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PART I

Bioventing Pilot Test Work Plan for

SOUTH GAS STATION (SGS) SITE
FUEL STORAGE AREA G (Site 1)
TRAVIS AIR FORCE BASE, CALIFORNIA

PART II

Draft Interim Pilot Test Results for

SOUTH GAS STATION (SGS) SITE
FUEL STORAGE AREA G (Site 1)
TRAVIS AIR FORCE BASE, CALIFORNIA

Prepared for

Air Force Center for Environmental Excellence
Brooks AFB, Texas
and Travis Air Force Base, California

September 1993

Prepared by

ENGINEERING-SCIENCE, INC.
DESIGN • RESEARCH • PLANNING
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Part I
Bioventing Pilot Test Work Plan for

South Gas Station (SGS) Site
Fuel Storage Area G (Site 1)
TRAVIS AIR FORCE BASE, CALIFORNIA

Prepared for

Air Force Center for Environmental Excellence
Brooks AFB, Texas
and
Travis Air Force Base, California

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Travis AFB, California

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PART I
BIOVENTING PILOT TEST WORK PLAN FOR SOUTH GAS STATION AND FUEL STORAGE AREA G (SITE 1) TRAVIS AFB, CALIFORNIA

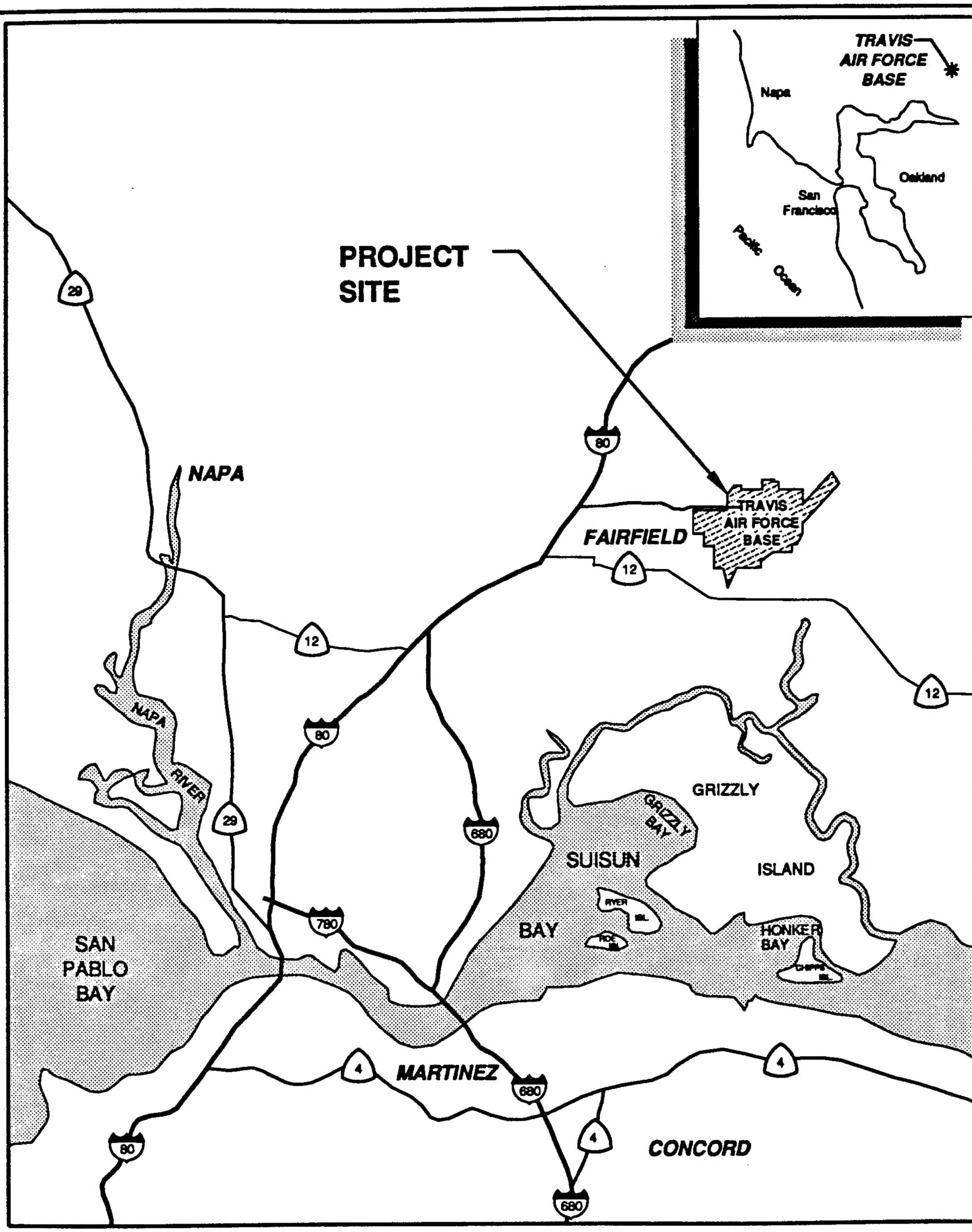
1.0 INTRODUCTION

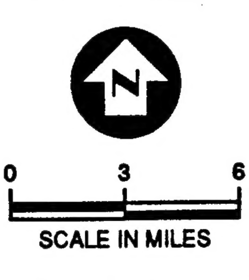
This Test Work Plan presents the scope of *in situ* bioventing pilot tests for treatment of fuel contaminated soils at the South Gas Station (SGS) Site and Fuel Storage Area G (Site 1) at Travis AFB, California. The site locations are shown in Figures 1.1 and 1.2. The pilot tests have three primary objectives: 1) to assess the potential for supplying oxygen throughout the fuel hydrocarbon-contaminated soil zone; 2) to determine the rate at which indigenous microorganisms will degrade the fuel in the soil when stimulated by oxygen rich soil gas; and 3) to evaluate the potential for sustaining these rates of fuel biodegradation until the fuel contamination is remediated below regulatory standards.

The bioventing pilot tests at Travis AFB, California will be divided into two test events. An initial pilot test will determine the technical feasibility and important design parameters such as air permeability, fuel biodegradation rates, radius of influence, and potential air emissions (requirements for emissions treatment). An extended (one-year) pilot test will determine the long-term application of this remedial technology to degrade hydrocarbons at each site. If bioventing proves to be applicable, pilot test data could be used to design and implement a bioventing remediation system. A significant amount of the fuel contamination should be biodegraded during the extended (one-year) pilot tests since the bioventing will take place within the most contaminated soils at each site.

Additional background information on the development and recent success of the bioventing technology is found in the document entitled "Test Plan and Technical Protocol for a Field Treatability Test for Bioventing" (Hinchee et al. 1992). This protocol document will also serve as the primary reference for pilot test well designs and detailed procedures which will be used during the tests.

Much of the background information on the SGS Site and Site 1 used in this Test Work Plan is derived from prior IRP studies and reports (Weston 1991 and Earth Technology 1992). This information includes some site maps, site histories, site geology and hydrogeology, and sampling and analytical data.



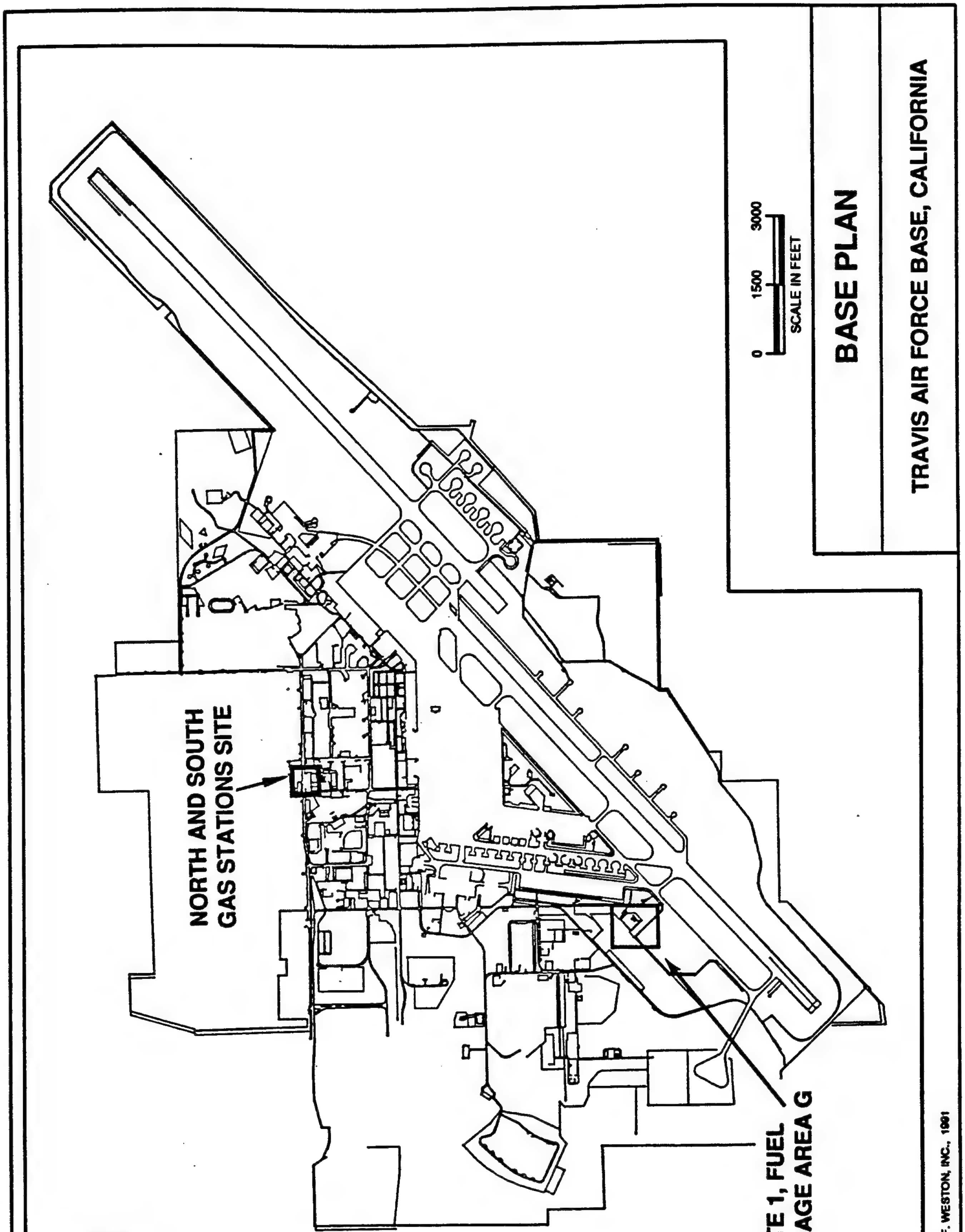


PROJECT SITE LOCATION

TRAVIS AIR FORCE BASE, CALIFORNIA

REV. 1 C234-08.DWG 08/31/93

FIGURE 1.2



BASE PLAN
TRAVIS AIR FORCE BASE, CALIFORNIA
0
1500
3000
SCALE IN FEET
NORTH AND SOUTH GAS STATIONS SITE
SITE 1, FUEL STORAGE AREA G
N
SOURCE: ROY F. WESTON, INC., 1991

2.0 SITE DESCRIPTION

2.1 South Gas Station (SGS) Site

The following sections provide a brief summary of the location, history, geology, and existing level of contamination at the SGS Site.

2.1.1 Site Location and Description

The SGS Site is located at Travis Air Force Base, Solano County, California, which is approximately 3 miles east of the town of Fairfield (Figure 1.1). Travis AFB is approximately midway between the cities of San Francisco and Sacramento.

The project site consists of two Base Exchange gasoline stations serving Travis AFB (Figure 2.1). The South Gas Station (Building 170) is the larger of the two and is located on the southeastern corner of the intersection of Travis and Broadway Avenues. The South Gas Station includes four pump islands and six underground storage tanks (USTs). The North Gas Station also includes pump islands and four USTs. Both gas stations have buildings, overhead canopies, and open spaces consisting of asphalt, concrete, and grass areas. The bioventing pilot test will be conducted at the South Gas Station based on initial IRP studies which indicate greater contamination at this site (Weston 1991).

2.1.2 Site History

Four USTs were installed at the South Gas Station in 1960 and two in 1974. The pipeline trench area between the UST pit and the southwestern pump island was excavated and the pipeline repaired in 1988 after investigations revealed a loss of over 3,800 gallons of gasoline due to a pipeline leak.

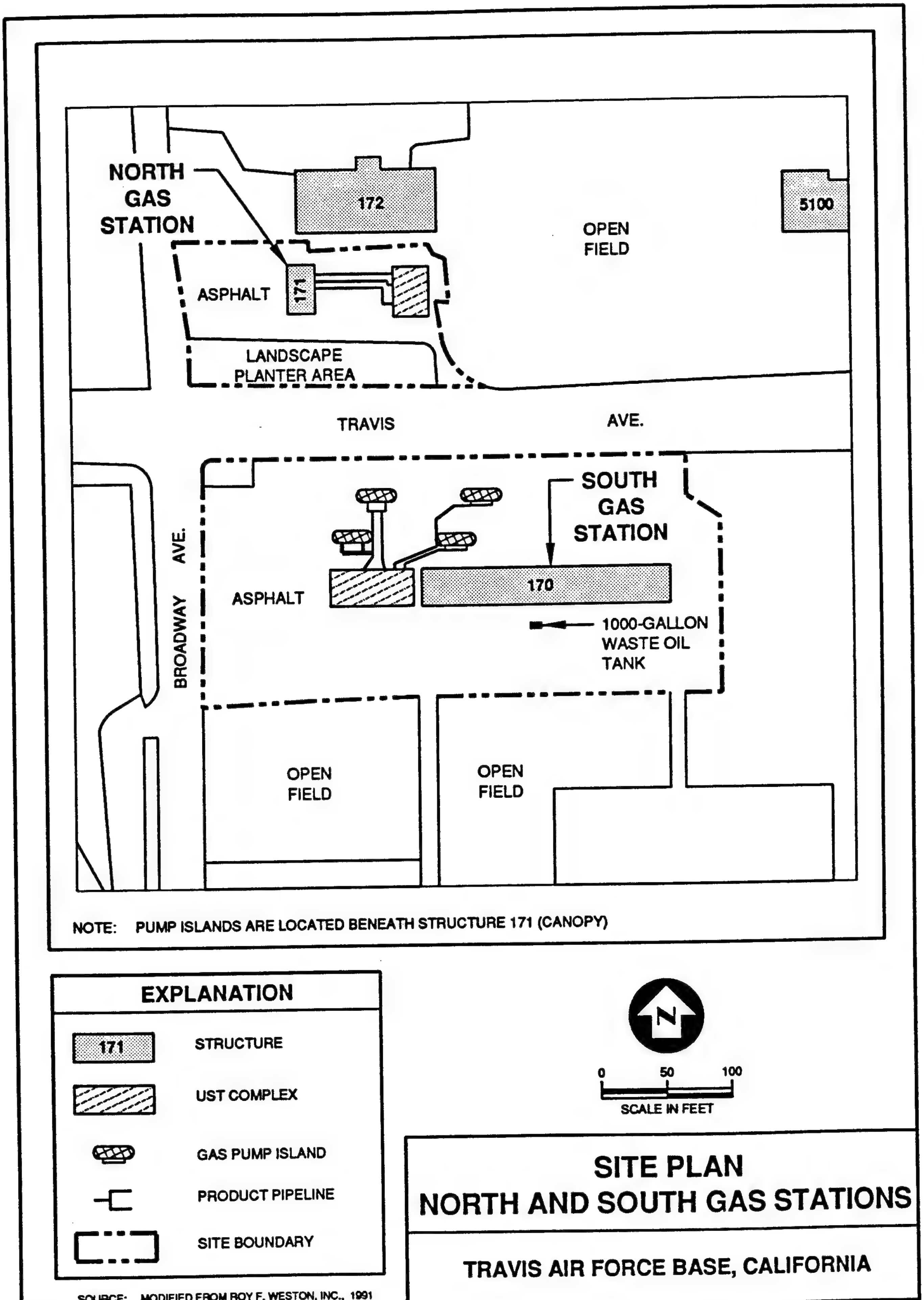
Environmental investigations at Travis AFB are a part of the DOD's Installation Restoration Program (IRP). The IRP is implemented with a phased approach, and the USAF has aligned the IRP to parallel the RI/FS approach required under CERCLA (Superfund), even though the North and South Gas Stations are not currently CERCLA sites. An IRP Stage 1 investigation of the site was conducted as a remedial investigation to provide information for a concurrent feasibility study and to evaluate potential remedial alternatives (Weston 1991).

2.1.3 Site Geology

As part of previous IRP investigations (Weston 1991), numerous soil borings were installed to collect subsurface soil samples. Figure 2.2 shows the location of the 14 soil borings, seven of which were converted to groundwater monitoring wells. Evaluation of the geology and hydrogeology in this Test Work Plan is based on these boreholes and wells.

Figure 2.3 is hydrogeologic cross-section A-A' constructed from four of the soil borings (including three monitoring wells) along a generally north to south line through the UST pit at the SGS Site. It shows the soil profile from the surface to 25 to 30 feet below ground surface (bgs).

FIGURE 2.1



SITE PLAN
NORTH AND SOUTH GAS STATIONS

TRAVIS AIR FORCE BASE, CALIFORNIA

SOURCE: MODIFIED FROM ROY F. WESTON, INC., 1991

C234-02.R2 11/01/92

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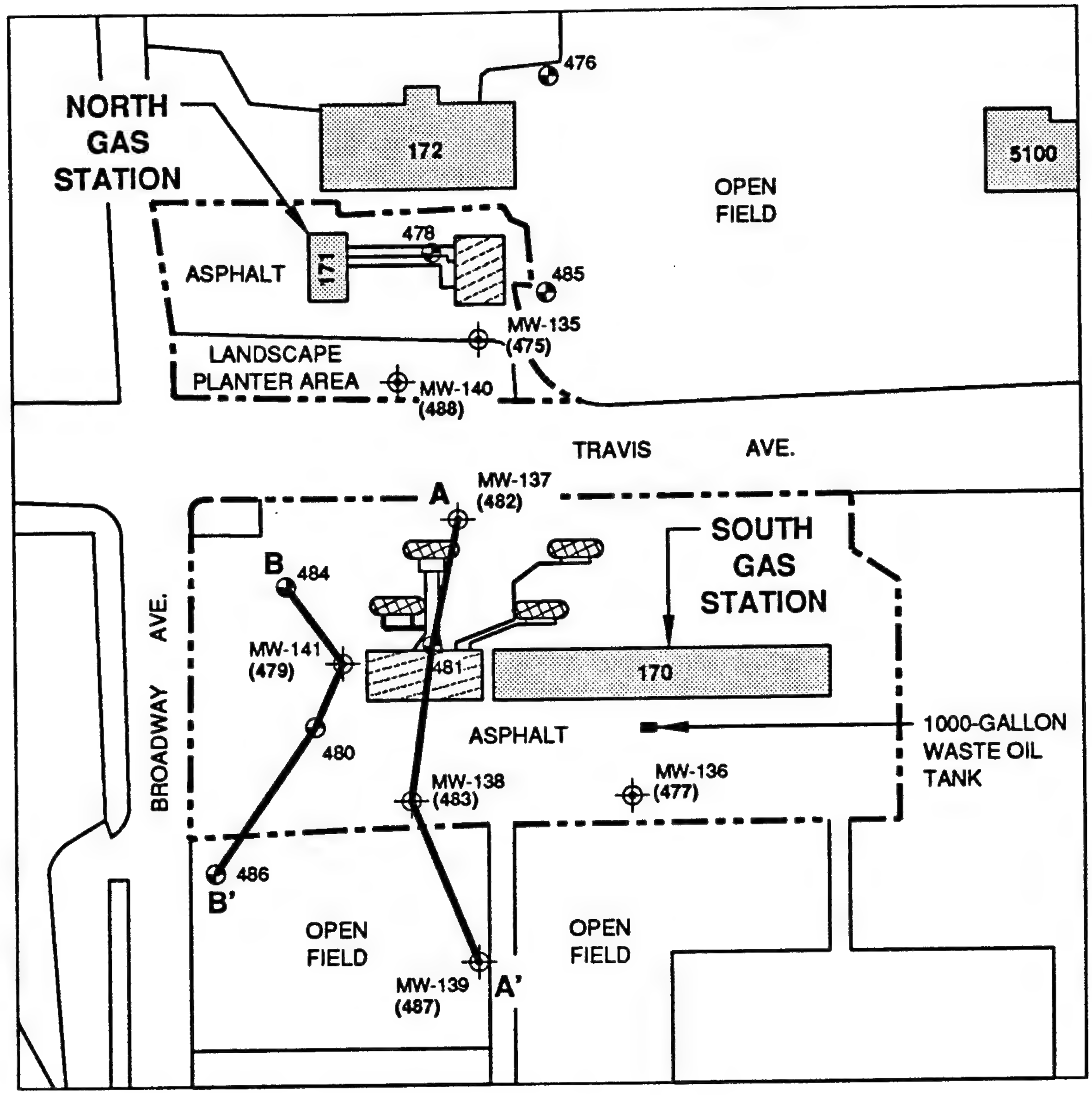
FIGURE 2.2



NOTE: PUMP ISLANDS ARE LOCATED BENEATH STRUCTURE 171 (CANOPY)

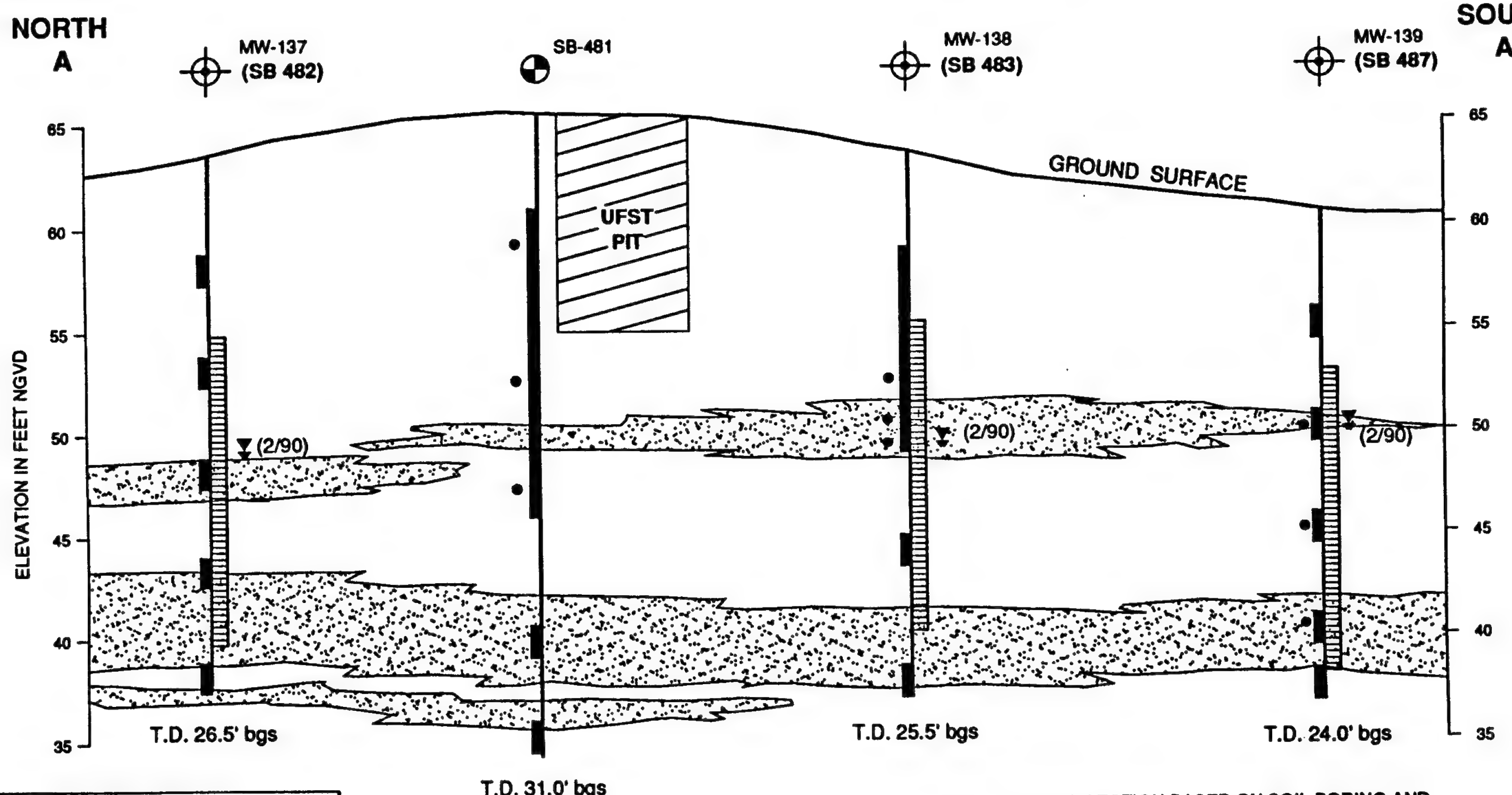
EXPLANATION	
171	STRUCTURE
	UST COMPLEX
	GAS PUMP ISLAND
	PRODUCT PIPELINE
	SITE BOUNDARY
MW-139 (487)	EXISTING MONITORING WELL WITH ID NUMBER (FORMER SOIL BORING)
486	EXISTING SOIL BORING
A A'	GEOLOGIC CROSS-SECTION

SOURCE: MODIFIED FROM WESTON, 1991

0 50 100
SCALE IN FEET

EXISTING SOIL BORING AND MONITORING WELL LOCATIONS NORTH AND SOUTH GAS STATIONS

TRAVIS AIR FORCE BASE, CALIFORNIA



NOTE: CROSS-SECTION BASED ON SOIL BORING AND SAMPLING DATA FROM WESTON (1991).

EXPLANATION

- MW-137 (SB 482) GROUNDWATER MONITORING WELL
- SB-481 SOIL BORING
- SOIL SAMPLE INTERVAL (DOT SHOWS SAMPLES ANALYZED)
- SCREEN INTERVAL
- GEOLOGIC CONTACT (DASHED WHERE INFERRED)
- WATER LEVEL (WITH DATE)

LITHOLOGIC DESCRIPTION

- FINE-GRAINED SAND WITH SILT
- CLAYS, SILTY CLAYS, AND CLAYEY SILTS

SCALE IN FEET (VERTICAL EXAGGERATION IS 5X)
5 0 / 0 50

HYDROGEOLOGIC CROSS-SECTION A-A'
SOUTH GAS STATION SITE

TRAVIS AIR FORCE BASE, CALIFORNIA

C234-18.R1 11/02/92

The near-surface soils at this site above the water table are predominantly clays, silty clays, and clayey silts. Possibly organic clays were encountered in the upper 5 feet of some borings, but they are not consistently present. Near and below the water table, the soils are predominantly fine-grained sands and silts interbedded with clays, silty clays and clayey silts. Figure 2.4 is hydrogeologic cross-section B-B' constructed from 4 soil borings (including 1 monitoring well) to the west of cross-section A-A'. It also follows a generally north to south direction and shows the soil profile from the surface to 25 to 30 feet bgs. Soil conditions are generally similar in the two cross-sections. However, the two separate sand intervals shown on cross-section A-A' appear to form one continuous and thicker unit in soil borings SB 479 (MW-141) and SB 480 (cross-section B-B'). In addition, this sand interval appears to pinch out to the north and south; it is very thin in soil boring SB 484 and is not present in SB 486.

No pumping tests have been conducted to determine aquifer characteristics and the possible hydraulic interconnectivity of stratigraphic units. However, the presence of similar contaminants in groundwater at each of the monitoring wells shown in the cross-section and the especially high concentrations in well MW-141 (SB 479) suggests that the sand layers are interconnected. Site contaminants are further discussed in the next section.

Groundwater levels were measured in January and February 1990 and found to be approximately 15 feet bgs. These water levels are found within the screened intervals. The data indicate that groundwater flow is to the west and southwest in the vicinity of the SGS Site, probably following the general topography. The gradient is gentle, approximately 0.005 ft/ft.

Since the soils above the shallow water table contain sufficient moisture and recent pilot studies have shown that bioventing can be effective even in low permeability soils (Downey et al. 1992), soils at the SGS Site may be acceptable for the bioventing technology.

2.1.4 Site Contaminants

The primary contaminants documented in soils and groundwater at the SGS Site (Weston 1991) are fuel residuals and aromatic hydrocarbons. Table 2.1 presents analytical data for each of the soil samples collected from seven of the nine soil borings at the SGS Site. Generally, the highest levels of soil contamination were found west of the UST pit (SB 479 and SB 480) and near the fuel pipeline (SB 481).

Table 2.2 presents analytical data for groundwater samples collected from the 5 monitoring wells at the South Gas Station. Floating, dark brown product, 1 to 2 inches thick was recovered on top of water in bailers during purging and sampling at Well MW-141, located immediately west of the UST pit at the SGS Site. No floating product was reported in any of the other wells. The highest levels of groundwater contamination were also found in Well MW-141, although significant amounts were also found in other wells.

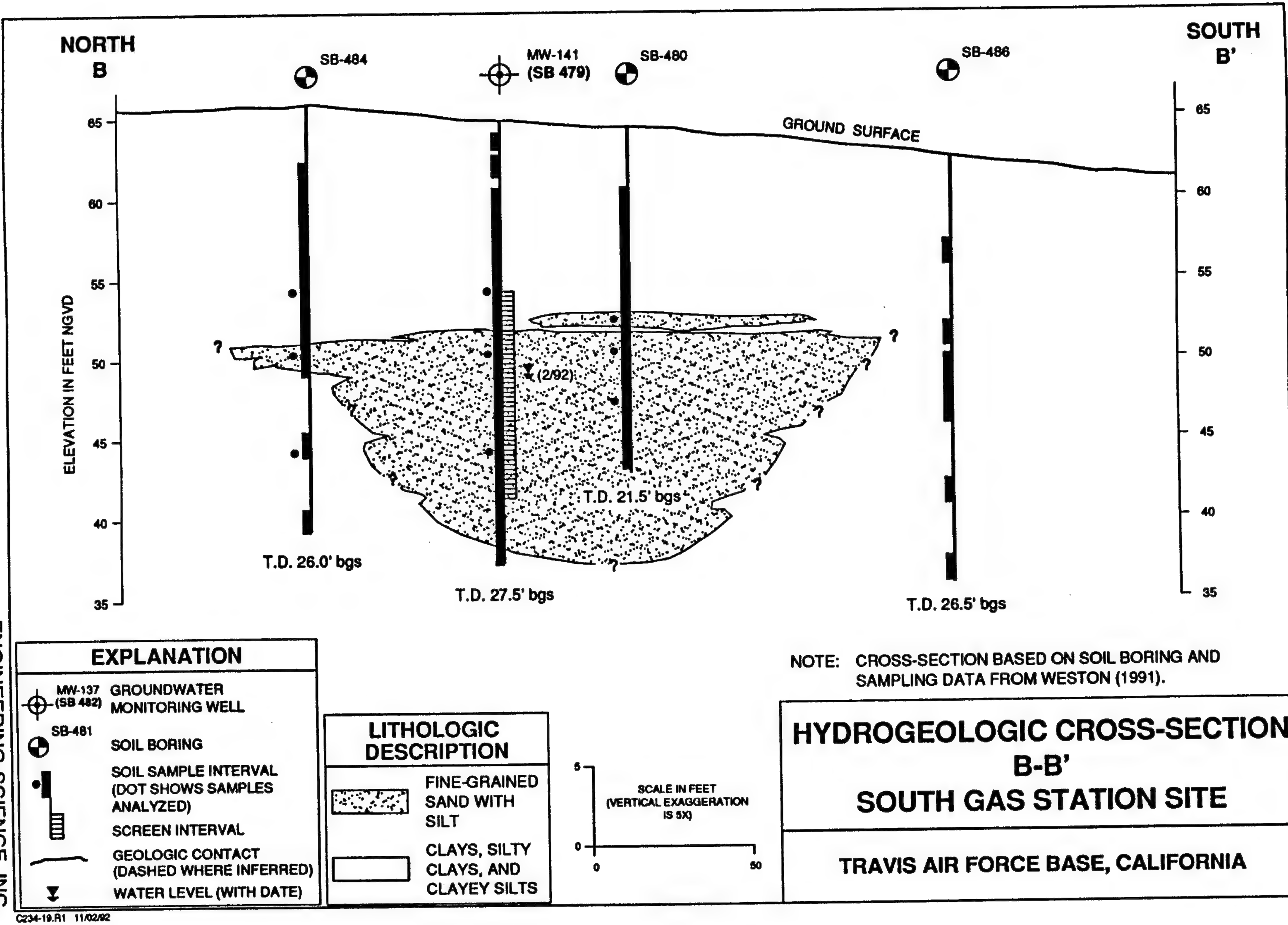


FIGURE 2.4

HYDROGEOLOGIC CROSS-SECTION B-B'
SOUTH GAS STATION SITE

TRAVIS AIR FORCE BASE, CALIFORNIA

ENGINEERING-SCIENCE, INC.

Table 2.1
Soil Contaminant Concentrations at South Gas Station, Travis AFB, California

Boring (Well)		Purgeable Petroleum HC		Extractable Petroleum HC				Purgeable Aromatics								Other	
	Method:	SW5030/SW8015		SW3550/SW8015				SW8020								DHS/LUFT	DHS-AB1803
	Analyte:	TPH-u	TPH-g	TPH-g	TPH-d1	TPH-d2	TPH-jf	Benzene	Toluene	Ethyl-benzene	Total Xylenes	Chloro-benzene	1,2-Dichloro-benzene	1,3-Dichloro-benzene	1,4-Dichloro-benzene	Organic Lead	1,2-Dibromo-ethane
	Depth (ft bgs)	concentrations in mg/kg															
SB 477 (MW-136)	8	NA	NA					0.0013	0.035			NA	NA	NA	NA		
	11	NA	NA						0.0046			NA	NA	NA	NA		
	14	NA	NA						0.018			NA	NA	NA	NA		
SB 479 (MW-141)	11	NA	NA						0.0015								
	15	NA	NA					520	2600	610	2900						
	20	NA	NA					0.27	0.009	0.018	0.11					3.9	
SB 480	12		4.0*					.0011*	0.0018*	0.00053*	0.0014*						
	14		14*	1600				11	72	24	120			10	13		
	17		4.0*					0.20	0.28	0.13	0.45			0.094	0.120		
SB 481	6	150	92	150				24	180	64	330			33	39		
	13		290	960													19
	18							0.14	0.18		0.22						
SB 482 (MW-137)	11							0.43			0.27						
	14					27		3.40	0.89	5.1	8.80			1.6	8.40	6.0	
	14(dup)							0.69	0.65								
	20										0.12						
SB 483 (MW-138)	13																
	15									0.10	0.23						
	16																
SB 484	12							0.68	0.071								
	15							0.73	0.084	0.087							
	21							0.086	0.094								

LEGEND

bgs : below ground surface
(shaded) : not detected (detection limits will vary depending upon dilution factor used)
NA : not analyzed
(dup) : duplicate
* : Detected under detection limit

TPH-u : Unknown total hydrocarbons
TPH-g : Total petroleum hydrocarbons as gasoline
TPH-d1 : Total petroleum hydrocarbons as #1 diesel
TPH-d2 : Total petroleum hydrocarbons as #2 diesel
TPH-jf : Total petroleum hydrocarbons as jet fuel
SOURCE : Roy F. Weston, Inc., 1991

bwptbl21

Table 2.2
Groundwater Contaminant Concentrations at South Gas Station, Travis AFB, California

	Purgeable Petroleum HC		Extractable Petroleum HC				Purgeable Aromatics				Other	
Method:	SW5030/SW8015		SW3510/SW8015				E602				DHS/LUFT	DHS-AB1803
Analyte:	TPH-u	TPH-g	TPH-g	TPH-d1	TPH-d2	TPH-jf	Benzene	Toluene	Ethyl-benzene	Total Xylenes	Organic Lead	1,2-Dibromo-ethane
Well	concentrations in $\mu g/L$											
MW-136												
MW-137			980				71	71	31	120		
MW-138		45,000	26,000				3,000	2,400	900	4,400		
MW-139		93,000	24,000				750	1,800	470*	1,800		
MW-141		230,000	9,800,000				54,000	91,000	6,600	32,000		
MW-141(dup)		270,000	6,500,000				16,000	33,000	11,000	50,000		

LEGEND

[shaded cell] : not detected (detection limits will vary depending upon dilution factor used)
(dup) : duplicate
* : Detected under detection limit

TPH-u: Unknown total hydrocarbons
TPH-g: Total petroleum hydrocarbons as gasoline
TPH-d1: Total petroleum hydrocarbons as #1 diesel
TPH-d2: Total petroleum hydrocarbons as #2 diesel
TPH-jf: Total petroleum hydrocarbons as jet fuel

SOURCE: Roy F. Weston, Inc., 1991

bwptbl22

2.2 Fuel Storage Area G (Site 1)

The following sections provide a brief summary of the location, history, geology, and existing level of contamination at Fuel Storage Area G (Site 1).

2.2.1 Site Location and Description

The project site is located east of Facility 977 and contains two above ground storage tanks each holding 210,000 gallons of JP4 jet fuel (Figure 2.5). Secondary containment is provided by earthen dikes. The site is fenced and considered a secured area. Fuel is pumped to and from the storage tanks through an underground pipeline system approximately 8 feet below grade. The underground pipes are typically 8-inch diameter cast iron, although major portions of the pipeline system near Site 1 are constructed of welded aluminum.

2.2.2 Site History

Site 1 was constructed in the early 1970's. One known above-ground release of 15,000 gallons of jet fuel occurred in 1978, resulting from overflow of a fuel/water separator after a valve was accidentally left open. Discharge from the fuel/water separator entered the storm sewer system which outlets to Union Creek. Although no other releases at the site are known, it is possible other leaks have occurred along the pipeline, at flange connections, or at valve pits.

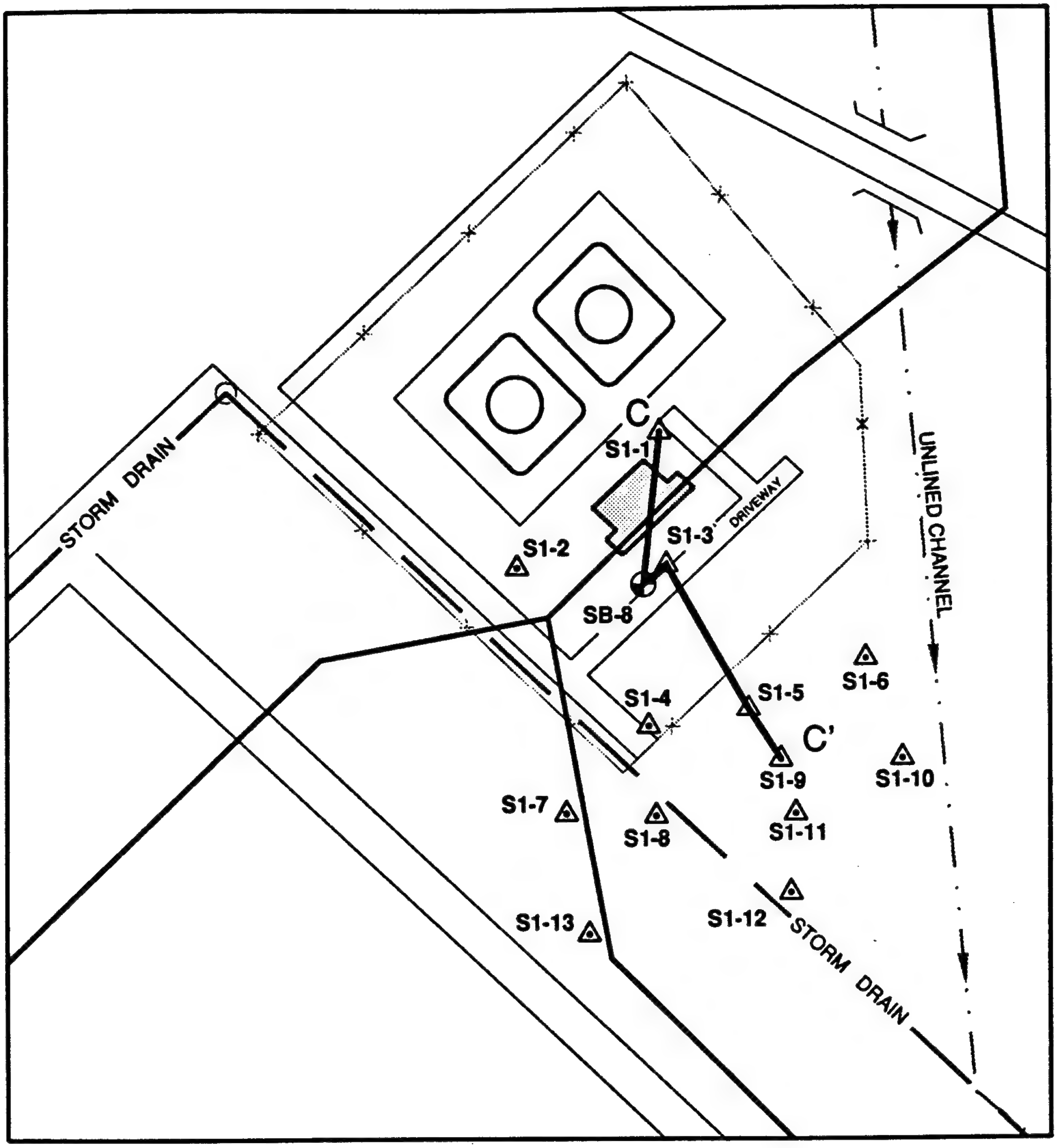
2.2.3 Site Geology

As part of previous IRP investigations (Earth Technology 1992), one soil boring and eighteen cone penetrometer tests (CPT) were performed at Site 1 to evaluate the subsurface soil types and collect subsurface groundwater and soil samples. Evaluation of the geology and hydrogeology in this Draft Test Work Plan is based on soil boring and test results from these locations and on an aquifer pumping test conducted by Earth Technology in March 1992.

Figure 2.5 shows the location of the soil boring and the CPT locations where soil samples were taken. Figure 2.6 is hydrogeologic cross-section C-C', constructed from three of the CPT results and one soil boring. It generally follows a north to south line from the earthen dikes to beyond the fence line and includes the area where the pilot test will take place. It shows the soil profile from the surface to 40 feet below ground surface (bgs).

The near surface soils at this site are predominantly clays, underlain by a sand interval approximately 10 to 20 feet in thickness. Groundwater levels were estimated from CPT profile data in September and November 1991 and ranged from approximately 12 to 15 feet bgs within the sand interval. Below the sand interval is a silt layer approximately 10 to 20 feet in thickness and then another clay layer at approximately 40 feet bgs with an unknown thickness.

One aquifer pumping test was conducted near Site 1 in March 1992. During the test, groundwater monitoring well MW-1 was pumped and drawdown and recovery response



EXPLANATION

SB-8	SOIL BORING
S1-2	CONE PENETROMETER TEST (CPT) LOCATION
	PRODUCT PIPELINE
	STRUCTURE
	FUEL TANK AND BERM
	FENCE
A — A'	GEOLOGIC CROSS-SECTION

SOURCE: MODIFIED FROM EARTH TECHNOLOGY, 1992

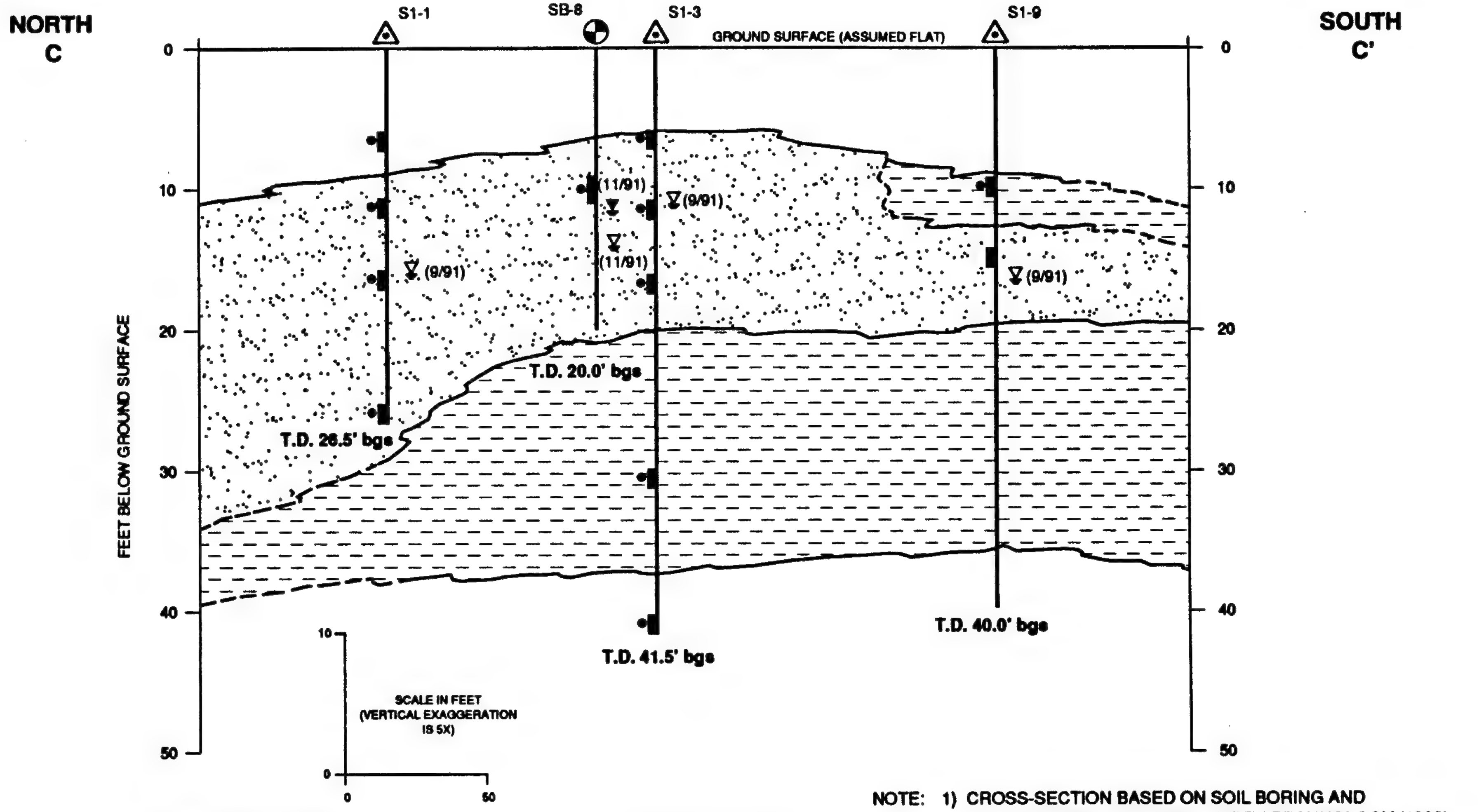
N

0 50 100

SCALE IN FEET

SOIL SAMPLING LOCATIONS SITE 1, FUEL STORAGE AREA G

TRAVIS AIR FORCE BASE, CALIFORNIA



NOTE: 1) CROSS-SECTION BASED ON SOIL BORING AND CPT SAMPLING DATA FROM EARTH TECHNOLOGY (1992).
2) WATER LEVELS ARE NOT CORRECTED FOR ELEVATION.

EXPLANATION

- SB-8 SOIL BORING
- S1-1 CONE PENETROMETER TEST (CPT) LOCATION
- SOIL SAMPLE INTERVAL (DOT SHOWS SAMPLES ANALYZED)
- GEOLOGIC CONTACT (DASHED WHERE INFERRED)
- WATER LEVEL FROM CPT (WITH DATE)
- FLOATING PRODUCT LEVEL (WITH DATE)

LITHOLOGIC DESCRIPTION

- SAND
- CLAYS
- SILTS

HYDROGEOLOGIC CROSS-SECTION C-C'
SITE 1, FUEL STORAGE AREA G

TRAVIS AIR FORCE BASE, CALIFORNIA

FIGURE 2.6

REV. 3 C234-25.DWG 07/14/93

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was measured in wells MW-223, MW-224, MW-116, and MW-310 (Figure 2.7). Results of the pumping test indicated that the aquifer was confined at the time of the test. However, soil boring and CPT results used to construct hydrogeologic cross-section C-C[1] indicate unconfined conditions; therefore, the aquifer may be seasonally confined or locally confined depending upon the thickness of the overlying clay layer.

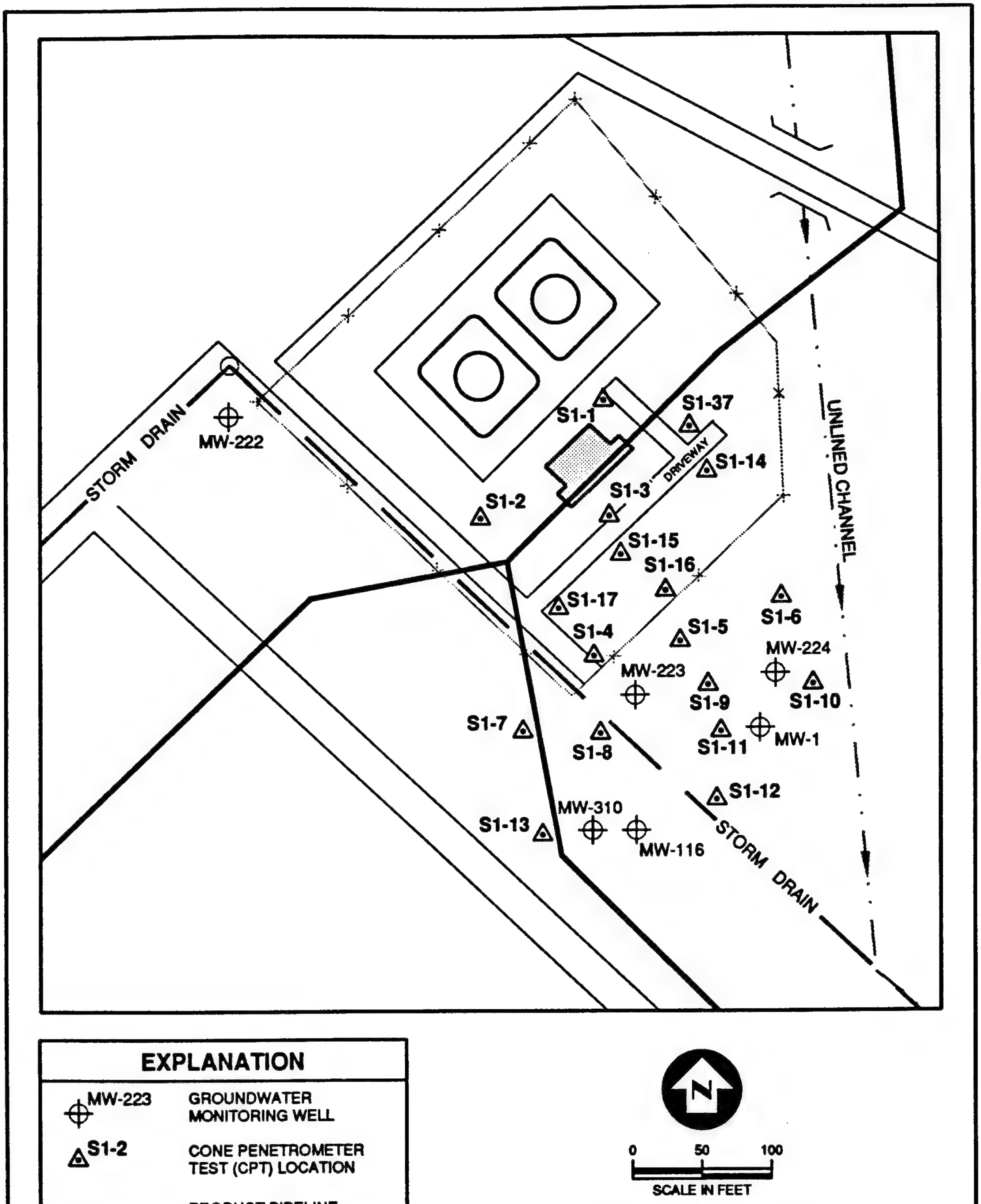
Groundwater flow appears to be generally to the south and southwest beneath Site 1 based on groundwater elevation data. The average hydraulic gradient is gentle, approximately 0.0075 ft/ft, and results of the pumping test indicate an average groundwater flow velocity of 0.10 ft/day (37 ft/yr).

Since the soils above the shallow water table contain sufficient moisture, and recent pilot studies have shown that bioventing can be effective even in low permeability soils (Downey et al. 1992), soils at Site 1 may be acceptable for the bioventing technology.

2.2.4 Site Contaminants

The primary contaminants documented in soils and groundwater at Site 1 are fuel residuals and aromatic hydrocarbons (Earth Technology 1992). Table 2.3 presents analytical data for each of the soil samples collected from the soil boring and 13 CPT locations (Figure 2.5). Generally, the highest levels of soil contamination were found between the structure and driveway (SB-8 and S1-3).

Table 2.4 presents analytical data for groundwater samples collected from the 6 monitoring wells and 16 CPT locations at Site 1 (Figure 2.7). The most prominent known groundwater contaminants are TPH-g (total petroleum hydrocarbons, as gasoline) and BTEX (benzene, toluene, ethylbenzene, and xylenes). Measurable floating product was found at six locations near Site 1: SB-8, S1-4, S1-17, MW-116, MW-223, and MW-224. SB-8 and S1-4 showed the greatest product thicknesses, 2.6 feet and 2.0 feet respectively. S1-17 showed a thickness of about 0.75 feet with the remaining three locations showing minor product films. Product migration appears to have followed the generally southern hydraulic gradient away from the initial spill site.



SOURCE: MODIFIED FROM EARTH TECHNOLOGY, 1992

GROUNDWATER SAMPLING LOCATIONS SITE 1, FUEL STORAGE AREA G

TRAVIS AIR FORCE BASE, CALIFORNIA

REV. 4 C234-28.DWG 08/31/93

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Table 2.3
Soil Contaminant Concentrations at Site 1, Fuel Storage Area G, Travis AFB, California

Location	Analyte: Depth (ft bgs)	TPH-g	TPH-d	Benzene	Toluene	Ethyl-benzene	Total Xylenes
		concentrations in mg/kg					
SB-8	10.0	3800		57	200	68	280
S1-1	6.5	0.46	NA				
	11.5	86	NA				
	16.5		NA				
	26.5		NA				
S1-2	15.0						
S1-3	6.5	43	NA				
	11.0[1]	730	NA	3.0	13	6.6	28
	11.5	420	NA	2.3	6.8	4.0	13
	16.5		NA				
	30.5	79					32
	41.0[1]		NA	0.043	0.027		
	41.5	73	54				2.6
S1-4	6.0[1]						
	6.5						
	6.5*		NA	NA	NA	NA	NA
S1-5	15.0	1.2	NA	0.021		0.018	0.054
S1-6	15.0	3.3		0.019		0.058	0.17
S1-7	5.5[1]	780	NA				2.3
	6.5						
S1-8	6.5						
S1-9	9.5[1]	4.5	NA			0.010	0.047
	10.0	180	NA				
	15.0						
S1-10	8.5	24	49			200	120
	13.5	7.8				140	570
S1-11	15.0		NA				
S1-12	14.5[1]						
	15.0						
S1-13	6.0		NA				

LEGEND

bgs: below ground surface
(shaded): not detected (detection limits will vary depending upon dilution factor used)
NA: not analyzed
*: duplicate
1: analyzed by fixed base laboratory
TPH-g: total petroleum hydrocarbons as gasoline
TPH-d: total petroleum hydrocarbons as diesel

NOTE: All analyses done by mobile laboratory except where noted.

SOURCE: Earth Technology, 1992

bwp2_t1
06/16/93

Table 2.4
Groundwater Contaminant Concentrations at Site 1, Fuel Storage Area G, Travis AFB, California

Analyte: Location	TPH-g	TPH-d	Benzene	Toluene	Ethyl-benzene	Total Xylenes
	concentrations in µg/L					
S1-1	8,400	NA	150	110	310	380
S1-2	11,000	NA	2,600	120	230	700
S1-3	400,000	NA	9,800	9,100	3,700	21,000
S1-5	12,000	NA	400		360	1,200
S1-6	13,000		660		740	1,500
S1-7	3,900		900		120	
S1-7[1]	8,600	1,800	84		36	7.6
S1-8	22,000	NA	2,200		680	1,000
S1-9	320	NA	4.3		6.2	39
S1-10	5,300	NA	310		410	280
S1-10[1]	14,000		390		400	220
S1-11	1,200	NA	4.8		33	58
S1-12	580					7.3
S1-13		NA				
S1-14	370,000		15,000	8,500	4,000	20,000
S1-14*		NA	NA	NA	NA	NA
S1-14[1]	64,000	1,200	9,500	8,700	2,300	9,700
S1-15	65,000	NA	9,500	2,800	1,200	3,700
S1-16	36,000	NA	4,300	1,300	660	1,800
S1-37	49,000	NA	21,000	82	900	1,600
MW-1[1]	450		3.1	1.2	5.5	17
MW-116	78		2.3		1.8	3.8
MW-222						
MW-223	5,700		170		140	540
MW-224	6,000		380	74	220	570
MW-224[1]	8,600		560	130	420	1,400
MW-310						

LEGEND

(dark shading): not detected (detection limits will vary depending upon dilution factor used)

NA: not analyzed

*: duplicate

1 : duplicate; analyzed by fixed base laboratory

TPH-g: total petroleum hydrocarbons as gasoline

TPH-d: total petroleum hydrocarbons as diesel

NOTE: All analyses done by mobile laboratory except where noted.

bwp2_t2

06/16/93

SOURCE: Earth Technology, 1992

3.0 SITE-SPECIFIC ACTIVITIES

The purpose of this section is to describe the work that will be performed by Engineering-Science, Inc. (ES) at the SGS Site and Site 1. Activities include siting and construction of a central vapor extraction well (VEW) or central vent well (VW), and vapor monitoring points (VMPs), an initial pilot test (an *in situ* respiration test and an air permeability test), and an extended (one-year) pilot test. Soil and soil gas sampling procedures and the blower configuration that will be used to introduce air (oxygen) into contaminated soils are also discussed in this section.

No dewatering or groundwater treatment will take place during bioventing pilot testing. Pilot test activities will be confined to unsaturated soils remediation. Existing monitoring wells will not be used as primary air injection or extraction wells; however, monitoring wells that have a portion of their screened interval above the water table may be used as VMPs or used to measure the composition of background soil gas. Monitoring wells expected to be possibly utilized as VMPs at the SGS Site are MW-137, MW-138, and MW-141. Existing monitoring wells at Site 1 are too far from the proposed central VW location to be useful as VMPs.

3.1 Location and Construction of Vapor Extraction Well and Vapor Monitoring Points

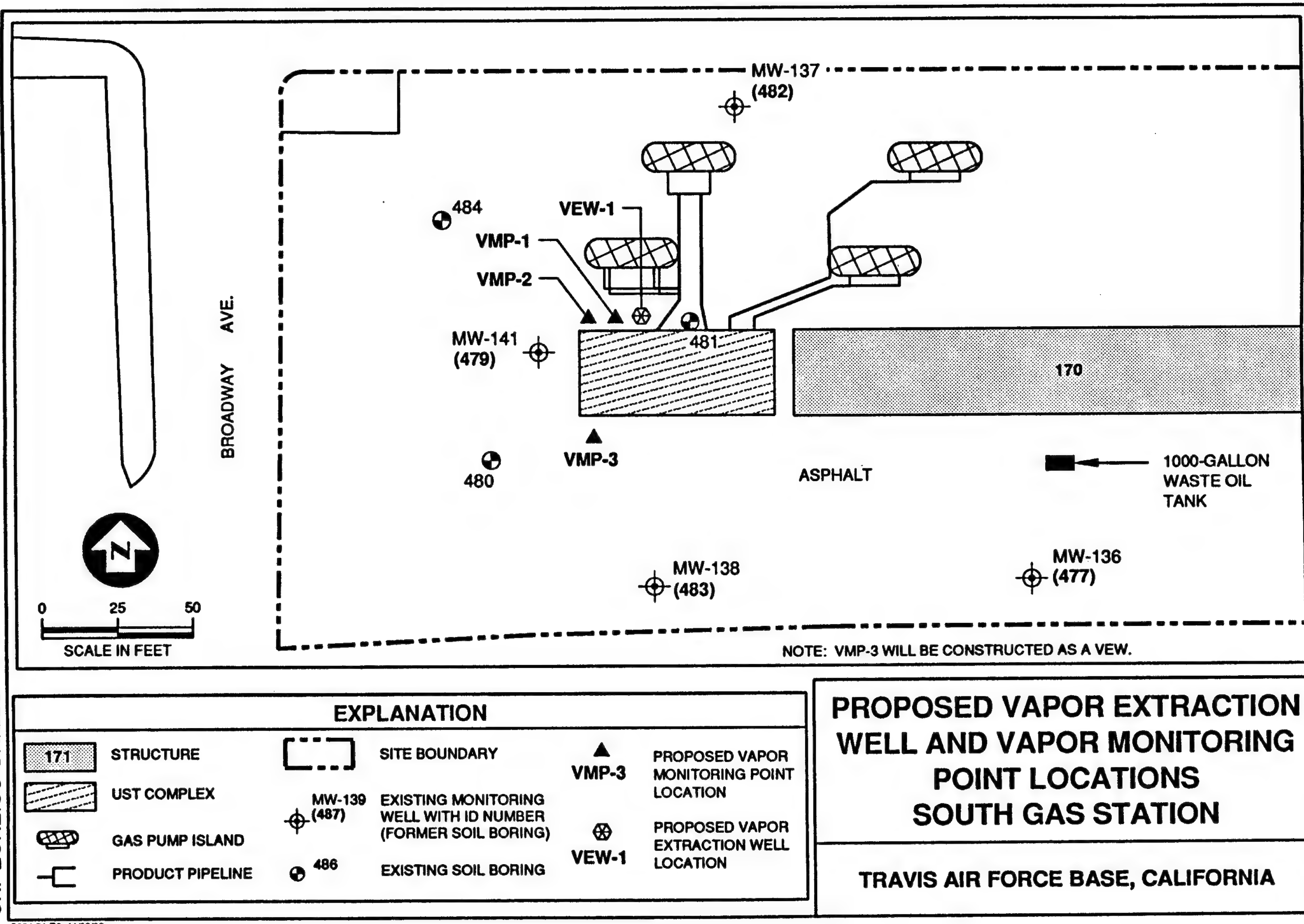
3.1.1 South Gas Station (SGS) Site

A general description of criteria for siting a central VEW and VMPs are included in the protocol document. Figure 3.1 indicates the proposed locations of the central VEW and VMPs. The location of these wells is consistent with the location of exploratory borings and monitoring well points presented in the RI/FS/treatability study work plan under the separate AFCEE IRP Stage 2 Order No. 23.

The final location of the VEW and VMPs may vary slightly from the proposed locations if evidence of significant fuel contamination is not observed in the borings. Based on site investigation data, the central VEW should be located north of the UST pit near the product pipelines west of Building 170. This area is expected to have high BTEX and TPH-g concentrations. Soils in this area are expected to be oxygen depleted (< 2 percent) and increased biological activity should be stimulated by oxygen-rich soil gas ventilation during both the initial and extended pilot tests.

The radius of venting influence around the central VEW is expected to be 20 to 50 feet based on the composition of the soils. Three VMPs will be located within a 50-foot radius of the central VEW. A fourth VMP will be located approximately 320 feet west of the central VEW (in the parking lot west of Broadway Ave.). This background VMP will be used to measure background levels of oxygen and carbon dioxide and to determine if inorganic or natural carbon sources are contributing to oxygen uptake during the *in situ* respiration test (Section 3.5). The location of the background VMP may need to be modified if field conditions indicate soil contamination is present at the initial background VMP location.

FIGURE 3.1



PROPOSED VAPOR EXTRACTION WELL AND VAPOR MONITORING POINT LOCATIONS SOUTH GAS STATION

TRAVIS AIR FORCE BASE, CALIFORNIA

C234-21.R0 11/02/92

ENGINEERING-SCIENCE, INC.

Figure 3.2 is a central VEW construction diagram for this site. The central VEW will be constructed of 4-inch ID Schedule 40 PVC, with a 10-foot interval of 0.04-inch slotted screen set between 5 and 15 feet bgs. Flush-threaded PVC casing and screen will be used with no organic solvents or glues. The filter pack will be clean, Lone Star sand with a 6-12 grain size and will be placed in the annular space of the screened interval. A 3-foot layer of bentonite will be placed directly over the filter pack. A complete seal is critical to prevent the short-circuiting of air from the surface during the bioventing test. The remainder of the annular space will be filled with bentonite/cement grout.

A typical multi-screen depth VMP installation for this site is shown in Figure 3.3. This installation will be applied to VMP-1, VMP-2 and VMP-4. Soil-gas oxygen and carbon dioxide concentrations will be monitored via vapor monitoring screens placed at depth intervals of approximately 7 feet and 12 feet bgs to provide good vertical coverage between the ground surface and the base of contamination in the vadose zone. Multi-depth monitoring will determine the concentration of oxygen across the entire soil profile and will be used to calculate oxygen utilization rates and fuel biodegradation rates at all monitored depths. The annular space between the vapor monitoring screen filter packs will be sealed with bentonite to isolate the monitoring intervals. As with the central VEW, several feet of bentonite will be used to seal the filter pack intervals. At the inner vapor monitoring point (VMP-1), thermocouples will also be installed at the same depths as the deepest and shallowest vapor monitoring screens to measure soil temperatures. Additional details on VEW and VMP construction are found in Section 4 of the protocol document.

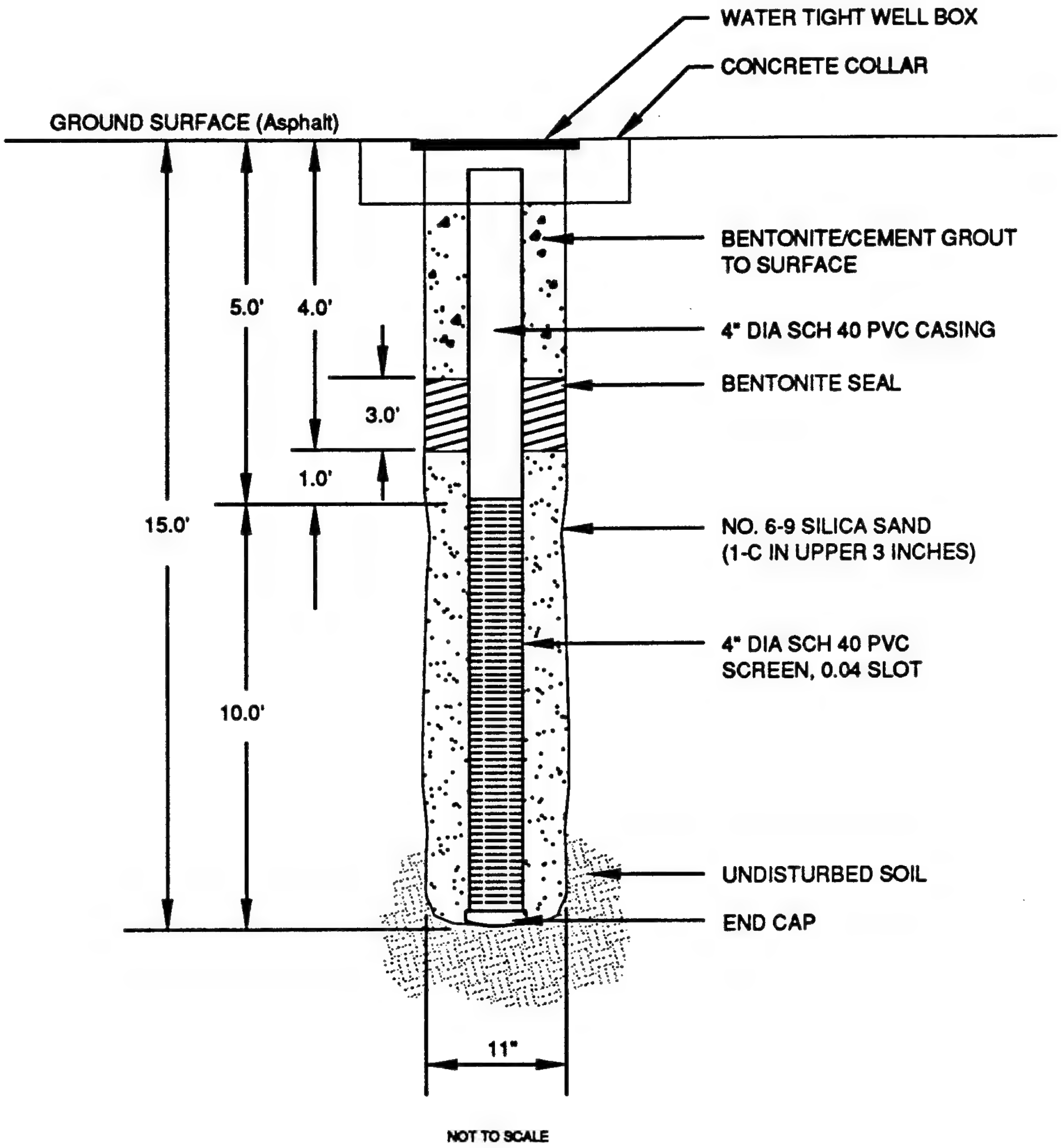
The VMP proposed south of the UST pit (VMP-3, Figure 3.1) will be constructed the same as the central VEW (VEW-1). During the initial pilot test, VMP-3 will be utilized as a Vapor Monitoring Point. However, for an extended (one-year) pilot test and a subsequent bioventing remediation system, VMP-3 could be utilized as a second Vapor Extraction Well.

3.1.2 Fuel Storage Area G (Site 1)

A general description of criteria for siting a central VW and VMPs are included in the protocol document. Figure 3.4 indicates the proposed locations of the central VW and VMPs.

The final location of the VW and VMPs may vary slightly from the proposed location if evidence of significant fuel contamination is not observed in the borings. Based on site investigation data, the central VW should be located between the fuel pipelines and the driveway near the location of S1-3. This area is expected to have high BTEX and TPH concentrations. Soils in this area are expected to be oxygen depleted (< 2 percent) and increased biological activity should be stimulated by oxygen-rich soil gas ventilation during both the initial and extended pilot tests.

The radius of venting influence around the central VW is expected to be 15 to 30 feet based on the composition of the soils. Three VMPs will be located within a 20-foot radius of the central VW. A fourth VMP will be located approximately 500 feet north of the central VW, outside of the fenced area of Site 1. This background VMP will be used



VAPOR EXTRACTION WELL CONSTRUCTION DIAGRAM SOUTH GAS STATION

TRAVIS AIR FORCE BASE, CALIFORNIA

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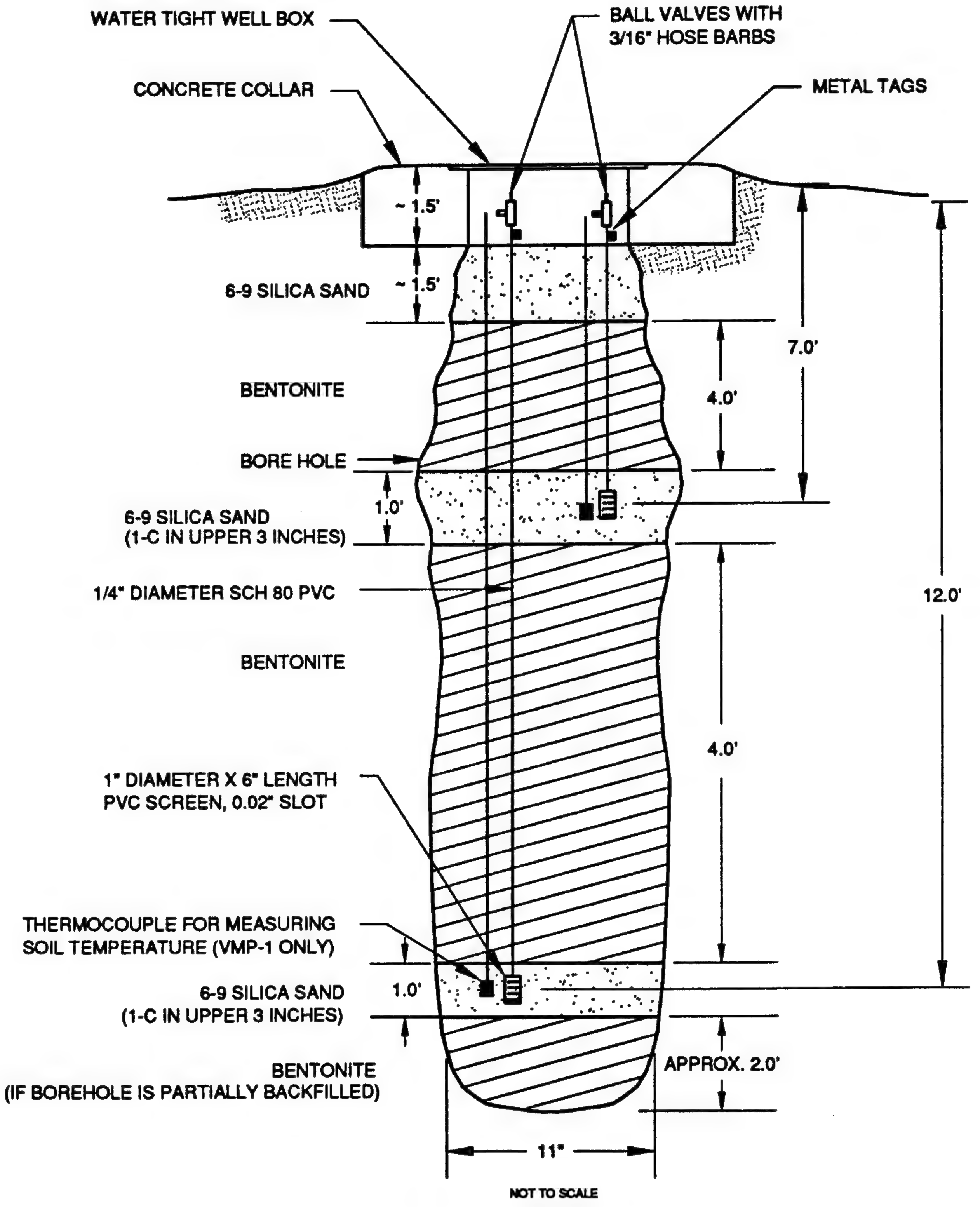
ENGINEERING-SCIENCE, INC.

FIGURE 3.3



NOTE: DEPTH TO SCREENS ARE APPROXIMATE. TRUE DEPTHS WILL BE DETERMINED IN THE FIELD BASED ON OBSERVED CONTAMINATION.

VAPOR MONITORING POINT CONSTRUCTION DIAGRAM SOUTH GAS STATION

TRAVIS AIR FORCE BASE, CALIFORNIA

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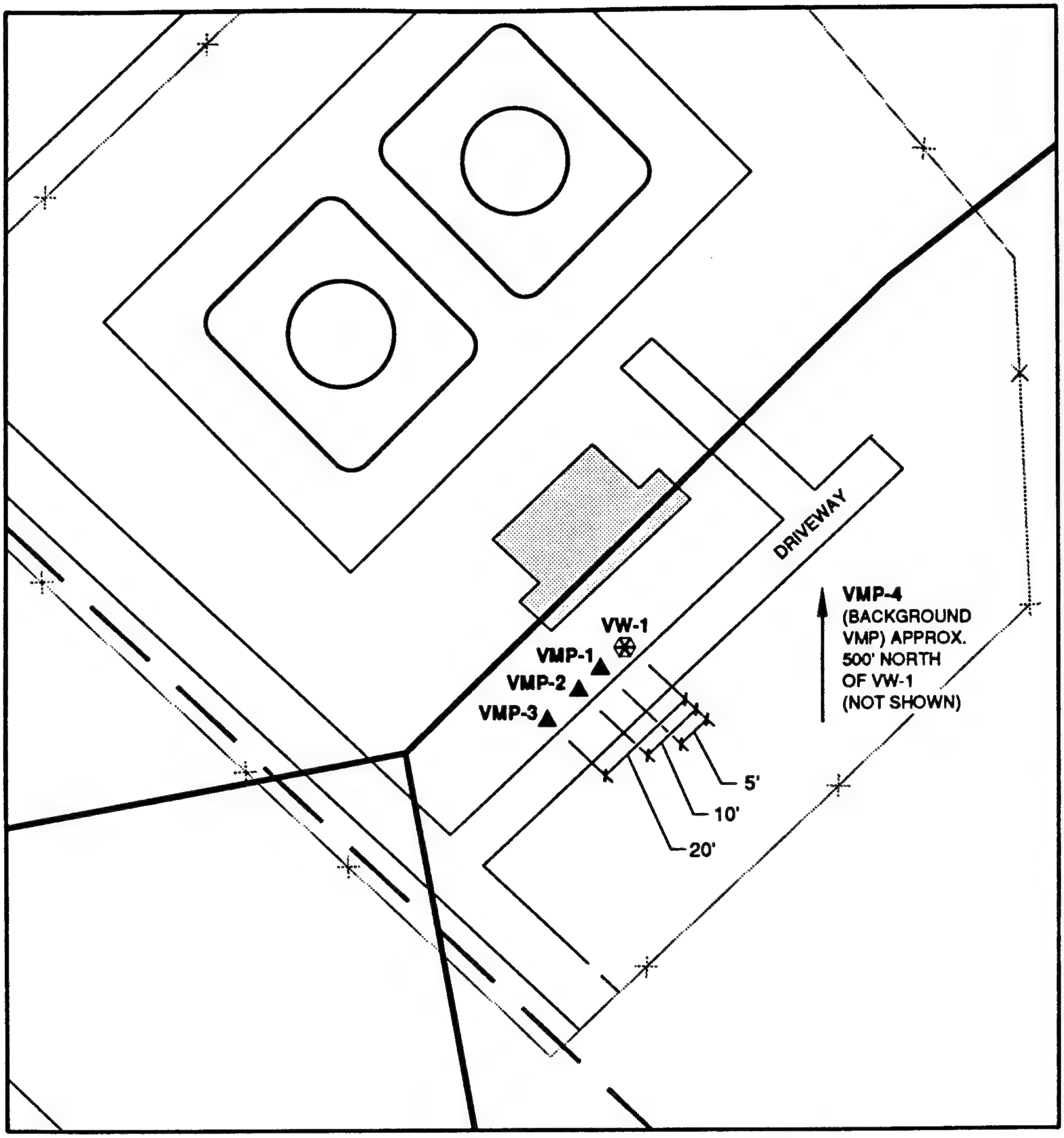
ENGINEERING-SCIENCE, INC.

FIGURE 3.4



EXPLANATION

VW-1	PROPOSED VENT WELL
VMP-2	PROPOSED VAPOR MONITORING POINT
	PRODUCT PIPELINE
	STRUCTURE
	FUEL TANK AND BERM
	STORM DRAIN
	FENCE

SOURCE: MODIFIED FROM EARTH TECHNOLOGY, 1992

PROPOSED VENT WELL AND VAPOR MONITORING POINT LOCATIONS SITE 1, FUEL STORAGE AREA G

TRAVIS AIR FORCE BASE, CALIFORNIA

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ENGINEERING-SCIENCE, INC.

to measure background levels of oxygen and carbon dioxide and to determine if inorganic or natural carbon sources are contributing to oxygen uptake during the *in situ* respiration test (Section 3.5). The location of the background VMP may need to be modified if field conditions indicate soil contamination is present at the initial background VMP location.

Figure 3.5 is a central VW construction diagram for this site. The central VW will be constructed of 4-inch ID Schedule 40 PVC casing, with a 5-foot interval of 0.04-inch slotted screen set between 6 and 11 feet bgs. Flush-threaded PVC casing and screen will be used with no organic solvents or glues. The filter pack will be clean Lone Star sand with a 6-12 grain size and will be placed in the annular space of the screened interval. A 3-foot layer of bentonite will be placed directly over the filter pack. A complete seal is critical to prevent the short-circuiting of air from the surface during the bioventing test.

A typical multi-screen depth VMP construction for this site is shown in Figure 3.6. This design will be applied to all VMPs. Soil-gas oxygen and carbon dioxide concentrations will be monitored via vapor monitoring screens placed at depth intervals of approximately 6 feet and 11 feet bgs to provide good vertical coverage between the ground surface and the base of contamination in the vadose zone. Multi-depth monitoring will determine the concentration of oxygen across the entire soil profile and will be used to calculate fuel biodegradation rates at all monitored depths. The annular space between the vapor monitoring screen filter packs will be sealed with bentonite to isolate the monitoring intervals. As with the central VW, several feet of bentonite will be used to seal the filter pack intervals. At the inner vapor monitoring point (VMP-1), thermocouples will be installed at the same depths as the deepest and shallowest vapor monitoring screens to measure soil temperatures. Additional details on VW and VMP construction are found in Section 4 of the protocol document.

3.2 Handling of Drill Cuttings

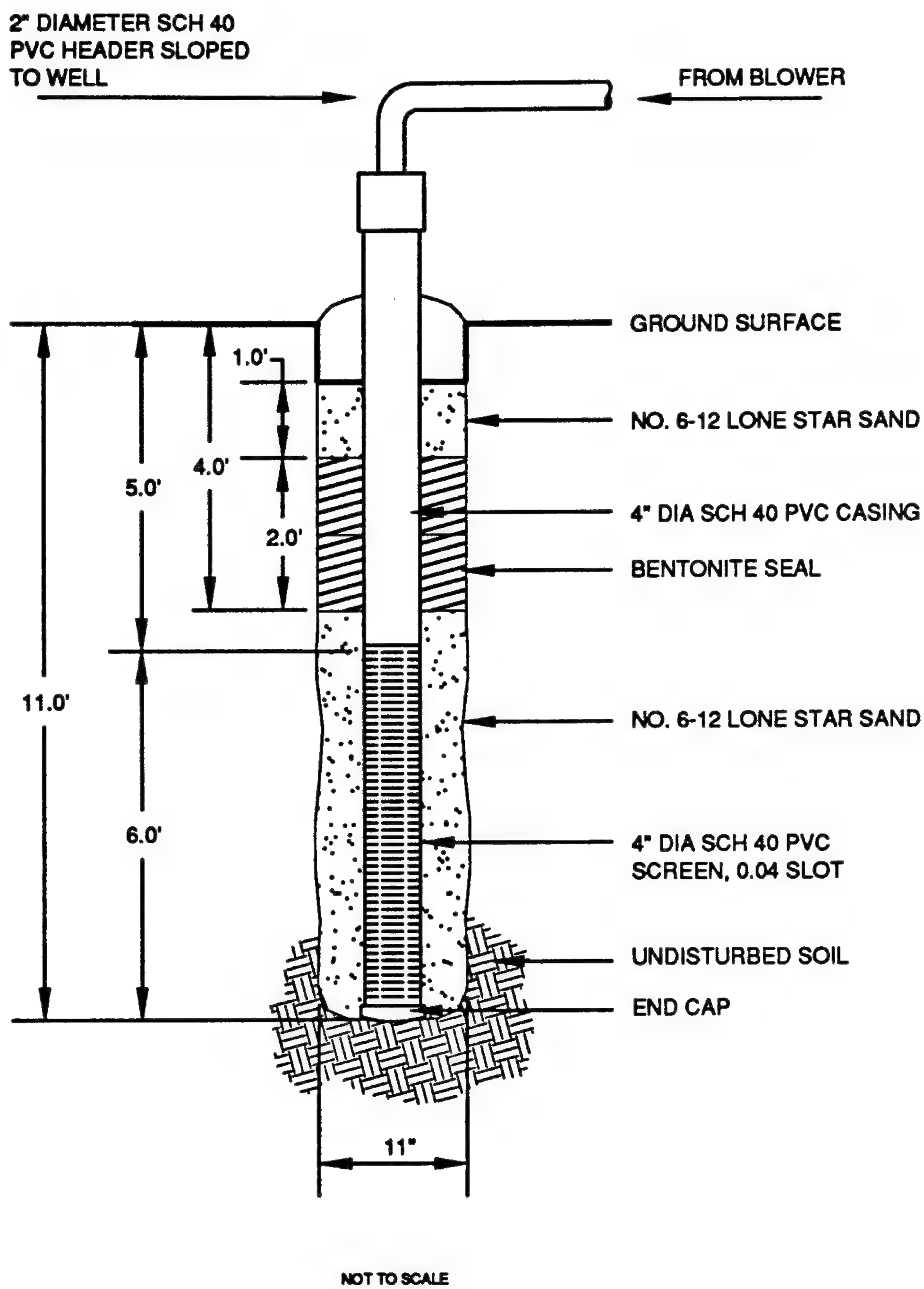
All soil cuttings will be gathered after each borehole is drilled and will be containerized on site in labelled U.S. DOT-approved 55-gallon drums. The drums will be transported to Building 1365 on base, where they will be stored. Soil cuttings will be stored on a boring-specific basis.

3.3 Soil and Soil-Gas Sampling

3.3.1 Soil Sampling

Three soil samples will be collected from each site during the installation of the VEW/VW and VMPs. One sample will be collected from the most contaminated interval of the central VEW/VW boring, and one sample will be collected from the most contaminated interval in each of the borings for the two inner VMPs (VMP-1 and VMP-2). Soil samples will be analyzed for total recoverable petroleum hydrocarbons (TRPH), benzene, toluene, ethylbenzene, and xylenes (BTEX), soil moisture, pH, grain-size distribution, alkalinity, total iron, and nutrients (total Kjeldahl nitrogen and phosphates).

FIGURE 3.5



NOTE: DEPTH OF SCREENED INTERVAL WILL BE NEAR THE BASE OF CONTAMINATION AS DETERMINED IN THE FIELD.

VENTING WELL CONSTRUCTION DIAGRAM SITE 1, FUEL STORAGE AREA G

TRAVIS AIR FORCE BASE, CALIFORNIA

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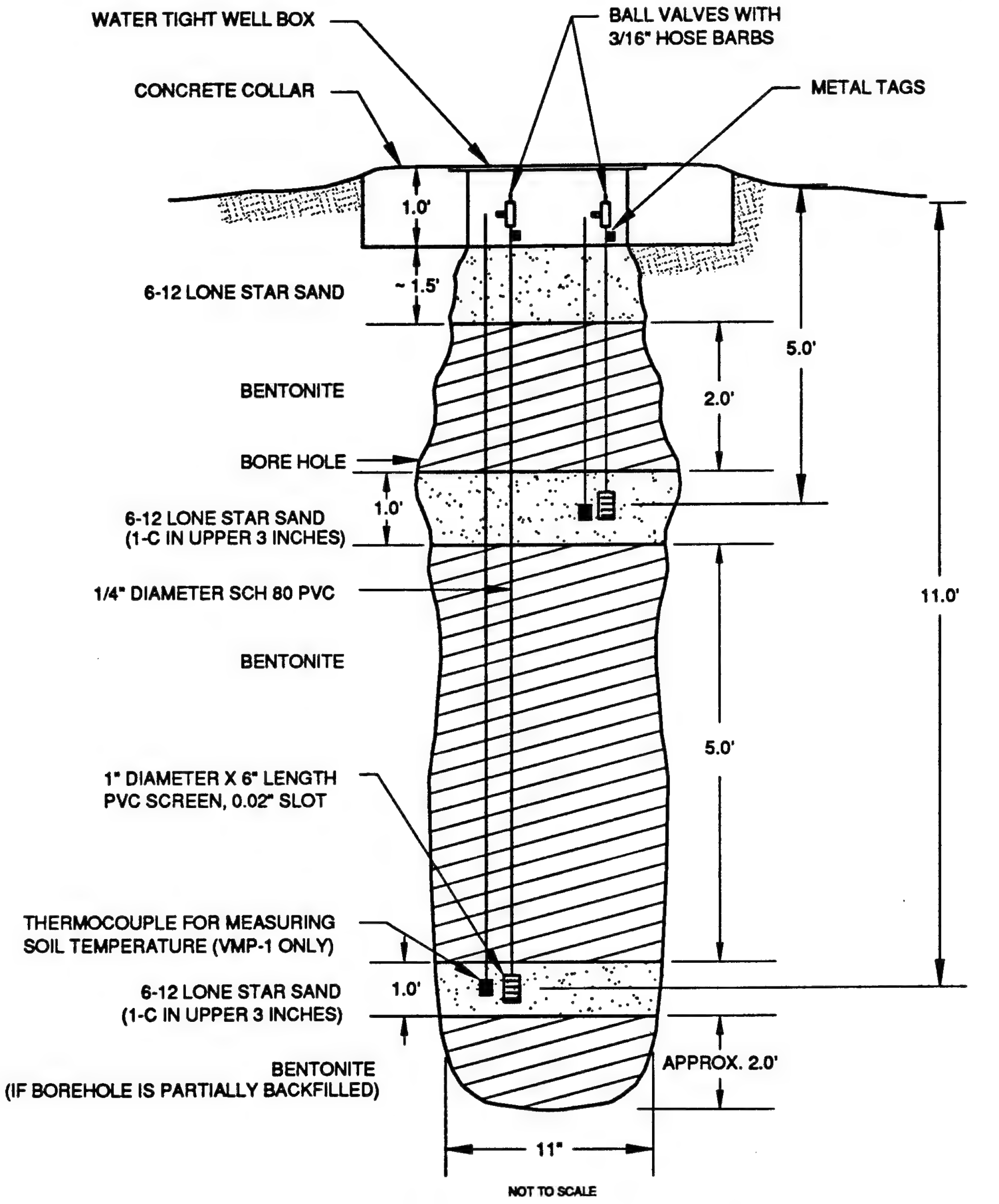
FIGURE 3.6



NOTE: DEPTH TO SCREENS ARE APPROXIMATE. TRUE DEPTHS WILL BE DETERMINED IN THE FIELD BASED ON OBSERVED CONTAMINATION.

VAPOR MONITORING POINT CONSTRUCTION DIAGRAM SITE 1, FUEL STORAGE AREA G

TRAVIS AIR FORCE BASE, CALIFORNIA

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ENGINEERING-SCIENCE, INC.

Samples will be collected using a split-spoon sampler containing brass tube liners. Soil samples collected in the brass tubes will be immediately trimmed and the ends sealed with Teflon® fabric held in place by plastic caps. Soil samples will be labeled following the nomenclature specified in the protocol document (Section 5.5), wrapped in plastic, and placed in an ice chest for shipment. A chain of custody form will be filled out and the ice chest shipped to the Engineering-Science (ES) laboratory in Berkeley, California, for analysis. This laboratory has been audited by the U.S. Air Force and meets all quality assurance/quality control and certification requirements for the State of California.

3.3.2 Soil-Gas Sampling

A total hydrocarbon vapor analyzer (THVA) (see protocol document Section 4.5.2) will be used during drilling to screen split spoon samples for determination of the most contaminated intervals. During the pilot test, initial and final soil-gas samples will be collected in Summa® canisters from the central VEW/VW and the VMPs closest to and furthest from the central VEW/VW (VMP-1 and VMP-3). These soil-gas samples will be used to predict potential air emissions and to determine the reduction in BTEX and total hydrocarbons.

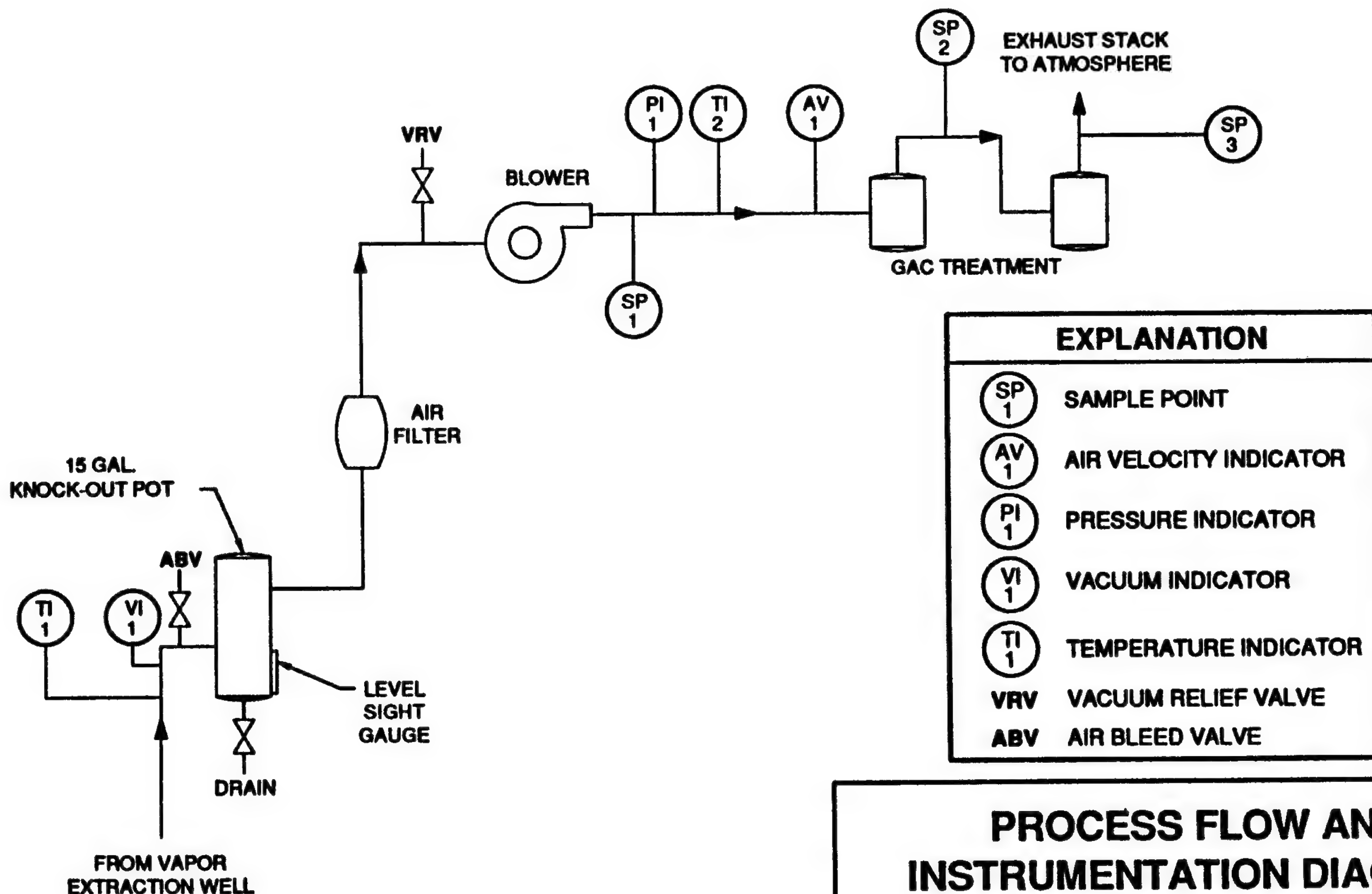
Soil-gas samples will be placed in an ice chest and packed to prevent excessive movement during shipment. Samples will not be sent on ice in order to prevent condensation of hydrocarbons. Samples will be analyzed for BTEX and total volatile hydrocarbons (TVH) using EPA Method TO-3. A chain of custody form will be filled out and the ice chest shipped to the Air Toxics Laboratory in Rancho Cordova, CA for analysis.

3.4 Blower System

A 3.0 horsepower, portable, positive displacement blower capable of extracting or injecting approximately 40 standard cubic feet per minute (scfm) at 4 psi (110 inches H_2O) will be used to conduct the initial air permeability tests at the sites. Figure 3.7 is a schematic of a typical air extraction system used for pilot testing. Figure 3.8 is a schematic of a typical air injection system used for pilot testing. The maximum power requirement anticipated for pilot testing is a 230 volt, single-phase, 30 amp service. Additional details on power supply requirements are described in Section 5.0, Base Support Requirements.

3.5 Air Permeability Tests

The objective of the air permeability tests is to determine the extent of the subsurface that can be oxygenated using a vacuum in a single VEW or pressure in a single VW. Air will be extracted at the SGS Site and injected at Site 1 using the portable blower unit and vacuum or pressure response will be measured at each VMP with differential pressure/vacuum gauges to determine the region influenced by the unit. Oxygen will be monitored in the VMPs to ascertain that oxygen levels in the soil increase as the result of air extraction or injection. One air permeability test lasting 2 to 8 hours will be performed. Additional details of the air permeability test are found in Section 5.6 of the attached protocol document.



PROCESS FLOW AND INSTRUMENTATION DIAGRAM BIOVENTING PILOT TEST SOUTH GAS STATION

TRAVIS AIR FORCE BASE, CALIFORNIA

FIGURE ~~3.5~~ 3.7

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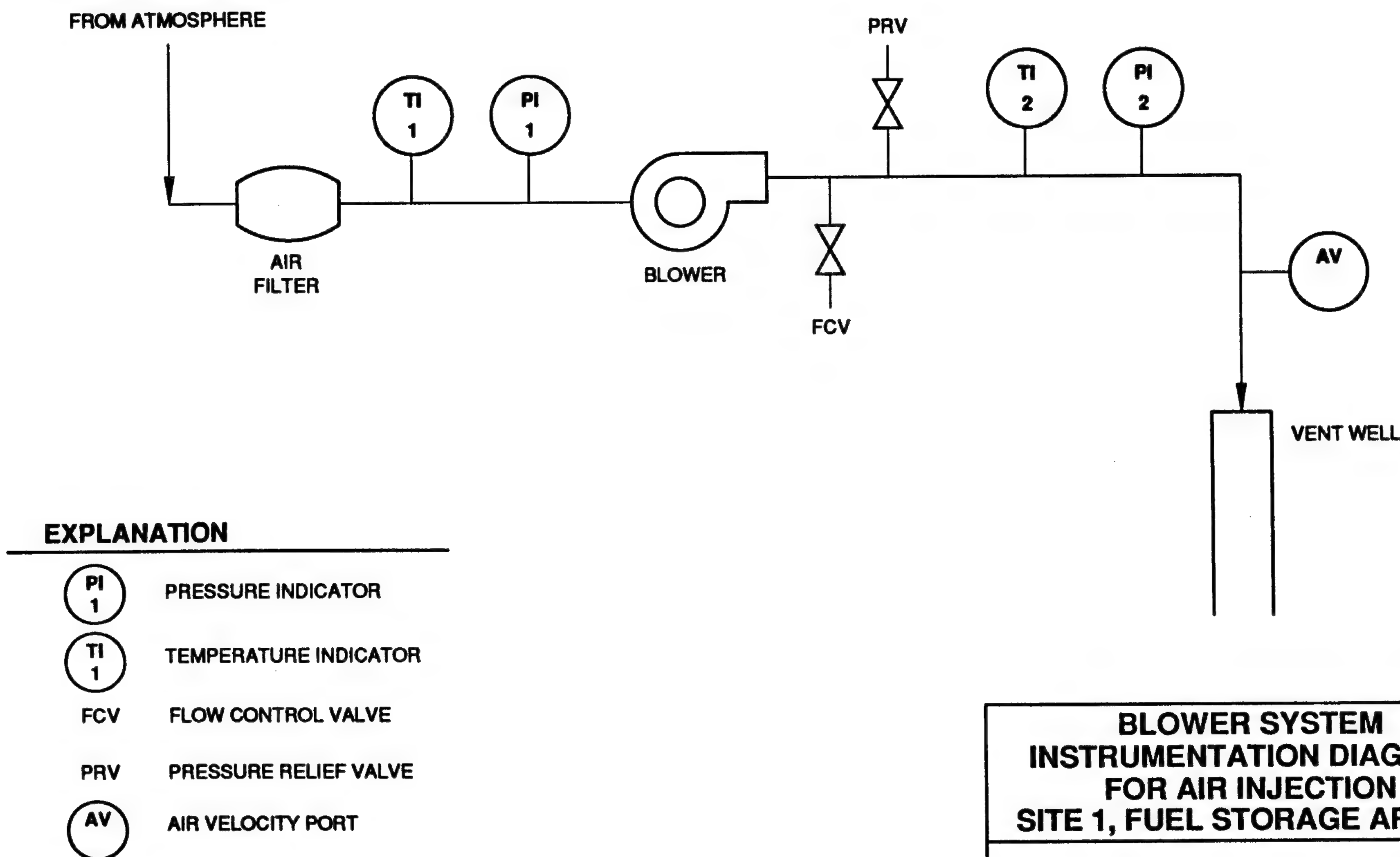

BLOWER SYSTEM INSTRUMENTATION DIAGRAM FOR AIR INJECTION SITE 1, FUEL STORAGE AREA G

TRAVIS AIR FORCE BASE, CALIFORNIA

3.6 *In Situ* Respiration Tests

The objective of the *in situ* respiration tests is to determine the rate at which soil bacteria will degrade the TPH contamination in the soil. Respiration tests will be performed at vapor monitoring screens (points) where bacterial degradation is indicated by initially low oxygen levels and elevated carbon dioxide concentrations in the soil gas. Air will be injected at points containing low levels of oxygen (below 2 percent, approximately) for approximately 20 hours to oxygenate local contaminated soils. At the end of the 20-hour air injection period, the air supply will be cut off and oxygen and carbon dioxide levels will be monitored for the following 12 to 72 hours. The decline in oxygen levels and increase in carbon dioxide levels over time will be used to estimate rates of bacterial degradation of fuel residuals. Helium, an inert gas, may also be injected at a concentration of 2 to 4 percent into vapor monitoring points used for respiration testing. Helium levels will be monitored during the respiration test to identify possible system leaks or short circuits to the surface. Additional details of the *in situ* respiration test procedures are found in Section 5.7 of the protocol document.

3.7 Air Emissions Monitoring

During the 2 to 8-hour air permeability test, a sample of the extracted soil-gas at the SGS Site will be collected in a Summa® cannister for TPH-volatiles and BTEX analysis using EPA Method TO-3. The purpose of this sample will be to determine potential potential emissions from the system and the requirements for potential emissions treatment at the site during the extended (one-year) pilot test.

3.8 Installation of Extended Bioventing Pilot Test System

An extended (one year) bioventing pilot test system will be installed at the SGS Site and Site 1 if the initial pilot tests successfully demonstrate the feasibility of providing oxygen throughout the contaminated soil profile. This one year of continuous venting will determine the long-term radius of influence, and the effect of time, available nutrients, and changing temperatures on fuel biodegradation rates. A Fixed Gast™ regenerative blower unit, sized appropriately for each site, will be installed as part of this extended pilot test system. The fixed blower will be housed in a small shed to provide protection from the weather and to minimize noise. This small "dog house" will be located in a low-traffic area. Base personnel are required to check the blower systems once each week to ensure that they are all operating and to record air injection pressures (extraction vacuums), flow rates, and temperatures. ES will provide a maintenance procedures manual, data collection sheets, and a brief training session.

Each system will be in operation for one year, and ES personnel will monitor it biannually. This biannual monitoring will consist of *in situ* respiration tests to monitor the long-term performance of these bioventing systems. Additionally, at the end of the extended (one-year) test, subsurface soil samples will be collected and analyzed at locations as close as possible to the original soil sample locations at each site in order to assess the degree of remediation during the first year of *in situ* treatments.

4.0 EXCEPTIONS TO PROTOCOL PROCEDURES

The procedures that will be used at each site to construct wells, measure the air permeability of the soil, and conduct the *in situ* respiration tests are described in Sections 4 and 5 of the protocol document. Two exceptions to the protocol should be noted. Groundwater levels in monitoring wells at both sites will be measured before borehole drilling to accurately designate maximum borehole depths. Groundwater levels will also be measured during pilot testing at the SGS Site to determine the impact of air extraction on localized groundwater elevation and flow. At the SGS Site, construction of VMP-3 will be the same as that for VEW-1; VMP-3 will be utilized as a vapor monitoring point during the initial pilot test and possibly as a second vapor extraction well for the extended bioventing pilot test system. No other exceptions to the protocol are anticipated.

5.0 BASE SUPPORT REQUIREMENTS

5.1 Test Preparation

The following base support for each site is needed prior to the arrival of the driller and the ES test team:

- Confirmation of regulatory permitting for the vapor extraction well, vent well, and vapor monitoring points and approval for the pilot test.
- Obtaining a base digging permit.
- Installation of a 230V/single phase/30 amp breaker box with one 230V receptacle, and two 110V receptacles.
- Provide any paperwork required to obtain gate passes and security badges for approximately three ES employees and two drillers. Vehicle passes will be needed for two trucks and a drill rig.
- Provide keys to the on-site groundwater monitoring wells.
- Provide a designated staging area for soil cuttings.

During the initial pilot tests, the following base support is needed:

- Twelve square feet of desk space and a telephone in a building located as near to the site as practical.
- The use of a fax machine for transmitting 15 to 20 pages of test results.
- A decontamination pad where the driller can clean augers between borings.

During the extended (one-year) pilot test, the following base support is needed:

- Check the blower system once a week to ensure that they are all operating and to record the air injection or extraction pressures, flow rates, and temperatures. ES will provide a brief training session on this procedure and a maintenance procedures manual with data collection sheets.
- If any blowers or motors stop working, notify Mr. Frederick Stanin or Mr. Michael Phelps, ES-Alameda, (510) 769-0100, or Mr. Doug Downey, ES-Denver, (303) 831-8100, or Mr. Sam Taffinder of the AFCEE, (210) 536-4366.
- Arrange site access for an ES technician to conduct *in situ* respiration tests at approximately six months and one year after the initial pilot tests.

6.0 PROJECT SCHEDULE

6.1 South Gas Station (SGS) Site

The following schedule is contingent upon timely approval of this pilot test work plan and completion of base support requirements.

Event	Date
Draft Test Work Plan to AFCEE/Travis AFB	09 November 1992
Approval to Proceed	20 November 1992
Begin VEW and VMP Construction	07 December 1992
Begin Initial Pilot Test	16 December 1992
Complete Initial Pilot Test	20 December 1992
Interim Results Report	To be determined
Respiration Test	To be determined
Final Respiration Test and Soil Sampling	To be determined

6.2 Fuel Storage Area G (Site 1)

The following schedule is contingent upon timely approval of this pilot test work plan and completion of base support requirements.

Event	Date
Draft Test Work Plan to AFCEE/Travis AFB	11 January 1993
Approval to Proceed	25 January 1993
Begin VW and VMP Construction	15 February 1993
Begin Initial Pilot Test	29 February 1993
Complete Initial Pilot Test	5 March 1993
Interim Results Report	To be determined
Respiration Test	To be determined
Final Respiration Test and Soil Sampling	To be determined

7.0 POINTS OF CONTACT

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Fax (510) 769-9244

8.0 REFERENCES

The Earth Technology Corporation, 1992, Technical memorandum. Installation Restoration Program, JP-4 Removal Investigation, Travis AFB, California, April.

Hinchee et al. 1992, Test Plan and Technical Protocol for a Field Treatability Test for Bioventing, U.S. Air Force Center for Environmental Excellence (AFCEE), January.

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Downey, D. C., P. R. Guest, R. N. Miller, 1992, Bioventing in Low Permeability Soils, In: Proceedings of the NGWA Outdoor Action Conference (in publication).

Part II

Draft
Interim Bioventing Pilot Test Results Report for

South Gas Station (SGS) Site
Fuel Storage Area G (Site 1)
TRAVIS AIR FORCE BASE, CALIFORNIA

Prepared for

Air Force Center for Environmental Excellence
Brooks AFB, Texas
and
Travis Air Force Base, California

September 1993

Prepared by

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42-04

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Travis AFB, California

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PART II
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Initial bioventing pilot tests were completed at two sites at Travis Air Force Base, California: the South Gas Station (SGS) Site; and Fuel Storage Area G (IRP Site 1). The purpose of this Part II Interim Report is to describe the results of the initial pilot test at each site and make specific recommendations for the extended (one-year) pilot tests which will determine the long-term impact of bioventing on site contaminants. Site histories, known contamination distributions and concentrations, and geologic/ hydrogeologic profiles are documented in Part I, Bioventing Pilot Test Work Plan.

1.0 PILOT TEST DESIGN AND CONSTRUCTION

1.1 South Gas Station (SGS) Site

1.1.1 Introduction

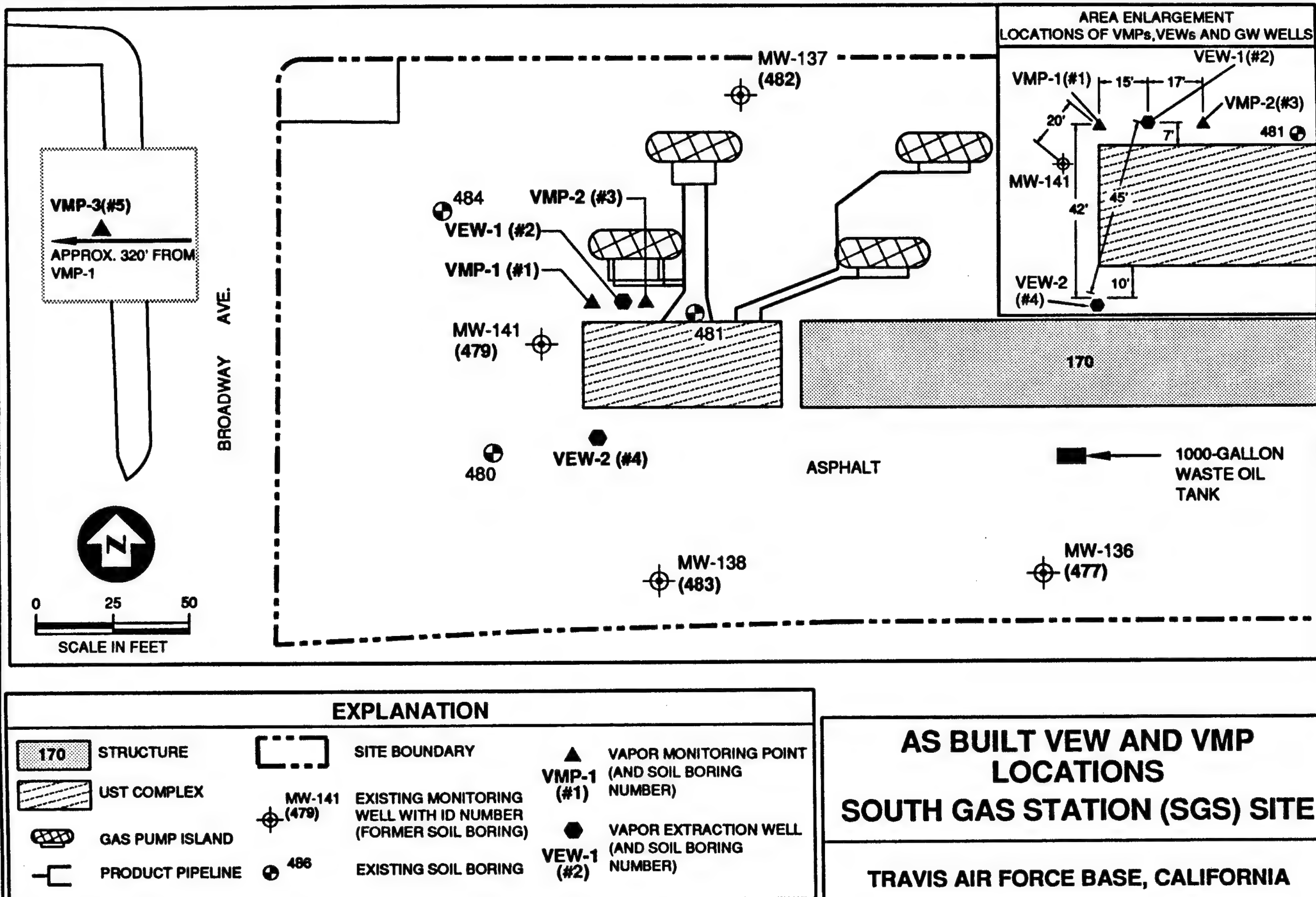
Installation of two Vapor Extraction Wells (VEWs) and three Vapor Monitoring Points (VMPs) was conducted at the SGS Site between 8 and 10 December 1992. Locations of the VEWs and VMPs are shown on Figure 1.1. The background VMP (VMP-3) was located approximately 320 feet west of VMP-1 adjacent to the parking lot west of Broadway Avenue. Borehole drilling services were provided by Gregg Drilling and Testing, Inc. of Pacheco, California. Soil sampling and well installation was directed on site by Mr. Henry Pietropaoli of the ES-Alameda office.

Five boreholes were drilled at the site and all were converted to VEWs or VMPs. No boreholes were abandoned since contamination observed during drilling was at sufficient levels for VW and VMP siting, and clean soils were encountered throughout the background VMP borehole. Soil samples from split-spoon and/or continuous soil samplers were collected for field organic vapor analysis (OVA) to determine appropriate VEW and VMP screened intervals and total depths. Both a total hydrocarbon vapor analyzer (THVA) and a photoionization detector (PID) were used to screen field samples. Soil samples were also collected for laboratory analysis. Table 1.1 summarizes pertinent borehole data.

1.1.2 Soil Profile

Figure 1.2 is a geologic cross-section of the pilot test site using data from the two VEWs, two VMPs (the background VMP is not shown), and a groundwater monitoring

FIGURE 1.1



AS BUILT VEW AND VMP LOCATIONS
SOUTH GAS STATION (SGS) SITE

TRAVIS AIR FORCE BASE, CALIFORNIA

REV. 3 C250-36.DWG 08/31/93

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TABLE 1.1
BOREHOLE, SOIL SAMPLE, VMP/VEW SUMMARY DATA
South Gas Station (SGS) Site
Travis AFB, California

BOREHOLE ID #	BOREHOLE TOTAL DEPTH (ft. bgs)	SPLIT-SPOON INTERVAL (ft. bgs)	THVA/PID HEADSPACE READINGS (PPM)	SOIL SAMPLE ID #	START DATE	COMPLETION DATE	COMPLETION DESIGNATION
1	15.5	5.0 - 6.5	4/26	-	8Dec92	9Dec92	VMP-1
		12.5 - 14.0	2200/2342	-			
		14.0 - 15.5	380/1580	TRsgs-VMP1-15.5			
2	15.5	5.0 - 6.5	79/1122	-	8Dec92	9Dec92	VEW-1
		9.5 - 11.0	0/152	-			
		11.0 - 12.5	560/1423	-			
		12.5 - 14.0	1800/2272	-			
		14.0 - 15.5	4000/3104	TRsgs-VEW1-15.5			
3	15.5	5.0 - 6.5	280/2713	-	8Dec92	9Dec92	VMP-2
		9.5 - 11.0	110/1872	-			
		14.0 - 15.5	26/3218	TRsgs-VMP2-15.5			
4	15.5	5.0 - 6.5	0/40	-	9Dec92	10Dec92	VEW-2
		10.0 - 11.5	9/51	-			
		12.5 - 14.0	1600/2057	-			
		14.0 - 15.5	1800/3075	-			
5	20.0	5.0 - 6.5	0/3	-	10Dec92	10Dec92	VMP-3
		9.5 - 11.0	0/3	-			
		14.0 - 15.5	0/6	-			
		18.5 - 20.0	0/16	-			

trvstab1.WK1

well installed during a previous site investigation. The interpreted soil profile is shown along with OVA readings, VEW and VMP screened intervals, groundwater levels, and Total Recoverable Petroleum Hydrocarbon (TRPH) concentrations from laboratory analysis of soil samples. The soil boring logs are included in Appendix A.

Below the surface asphalt material, the observed soil profile to approximately 13 feet bgs at the SGS Site is predominantly clay to silty clay with some clayey silt. In all the borings at the SGS Site, with the exception of the VMP-2 borehole, this silty clay interval exhibited a noticeable fuel odor throughout with some blue-green to green-gray discoloration. Soils in the VMP-2 borehole were not reported as discolored and had less-noticeable fuel odor.

In all the borings except VMP-2, the soils below the silty clays (at approximately 13 feet bgs) were fine to medium-grained sands to silty sands. This sand, where present, exhibited some green to blue-green discoloration with a noticeable fuel odor. The thickness of this sand is unknown, since the borings were advanced to only 15.5 feet bgs. However the boring for MW-141, a groundwater monitoring well that was installed during a previous site investigation (Weston 1991), encountered this sand from approximately 13 feet to 25 feet bgs. The cross-sections presented in the Bioventing Test Work Plan (Part I) indicate this sand to have great variability in both thickness and lateral extent. In boring VMP-2, clay and silty clay were encountered to the total depth.

Groundwater was encountered in two of the four borings at the SGS site. In boreholes VMP-2 and VEW-2, groundwater was found at the bottom of each boring (15.5 feet bgs). No free product was noticed in either borehole. This depth to groundwater was consistent with the water level as measured in MW-141 prior to drilling operations.

The soils encountered in the background VMP (VMP-3) located approximately 320 feet west of VMP-1 were somewhat similar to the soil at the SGS Site. However, the clay, silty clay, and fine-grained sand in VMP-3 was much harder and indurated, indicating a higher degree of lithification. No fuel odors were detected in the VMP-3 soils. The borehole was advanced to 20 feet bgs and groundwater was not observed during drilling operations.

1.1.3 Vapor Extraction Wells

Two VEWs (VEW-1 and VEW-2) were installed in locations of noticeably fuel-stained and odorous soils following procedures described in the protocol document (Hinchee et al., 1992). VEW-1 was installed 7 feet north of the UST complex and VEW-2 was installed 10 feet south of the southwest corner of the UST complex. Table 1.2 shows construction data and Figure 1.3 shows construction details for both VEWs.

Each VEW was constructed using 4-inch ID, Schedule 40 PVC casing and slotted screen (0.040-inch slot size). The annular space adjacent to the screen was filled with size 6-12 Lone Star sand (filter pack material) from the base of the borehole to 1 foot above the top of the screen. A small amount of size 1-C Lone Star sand was added to the top of this interval to inhibit penetration of the overlying bentonite seal material into the filter pack interval.

FIGURE 1.2

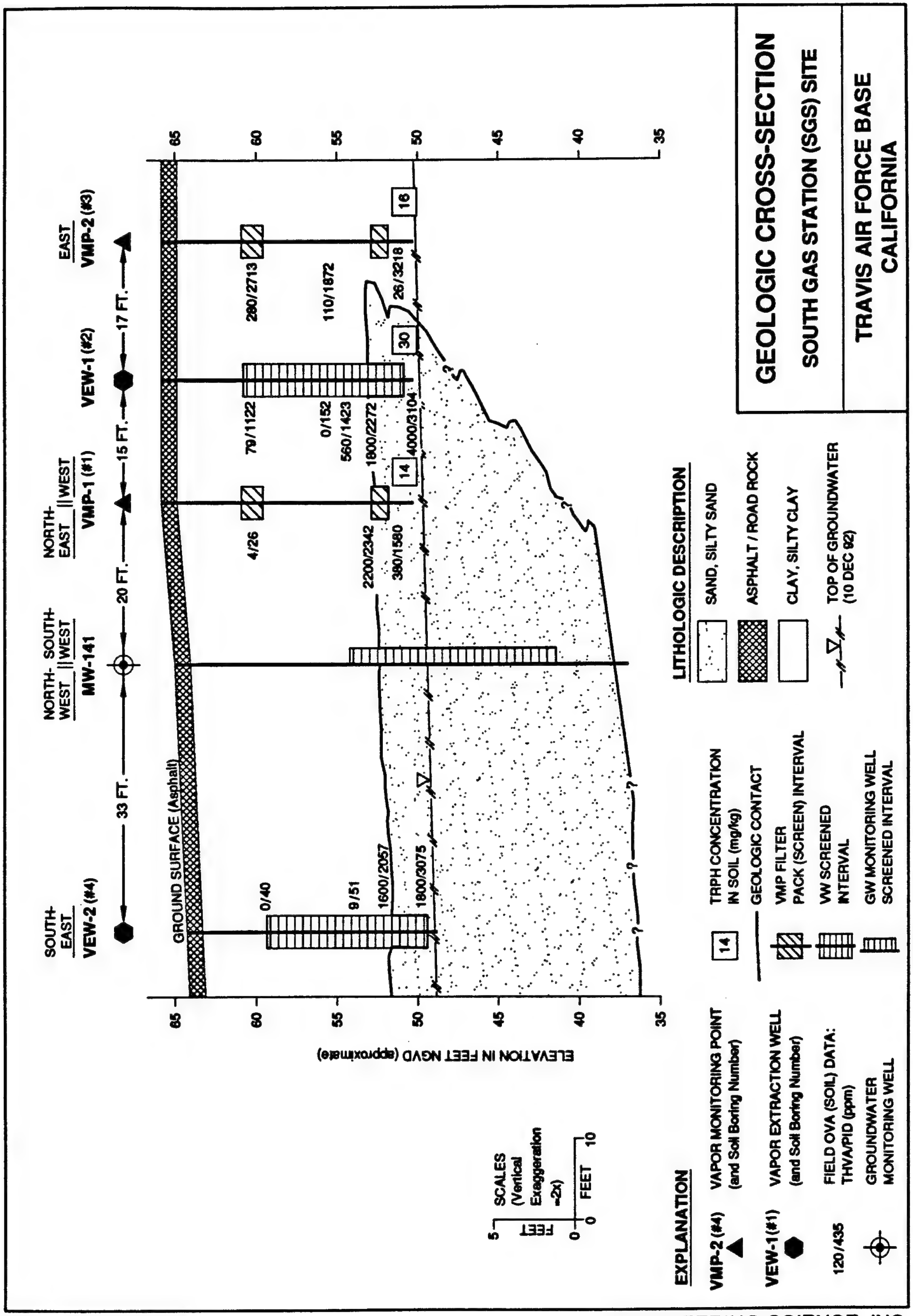

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TABLE 1.2

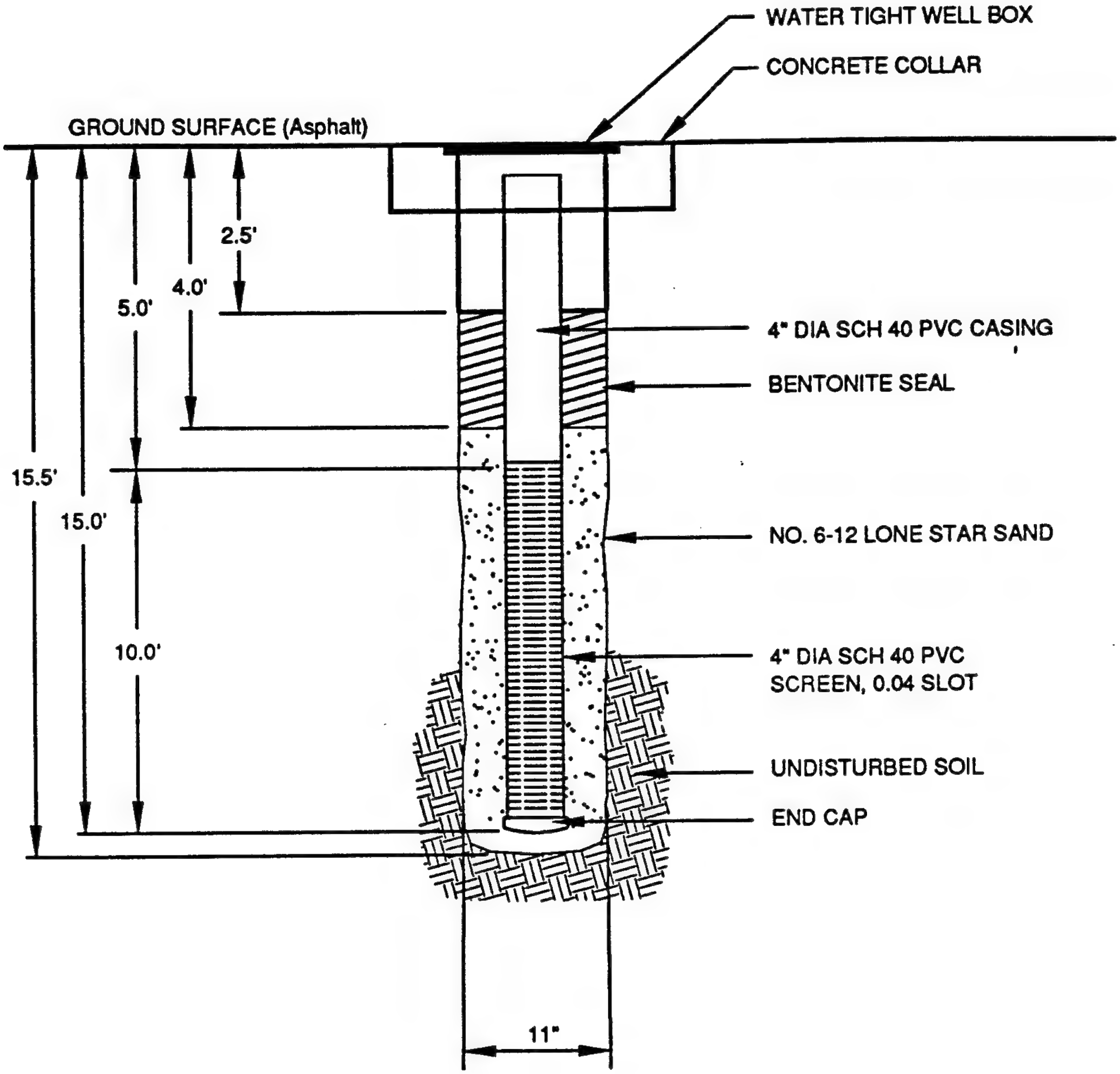
VMP/VEW CONSTRUCTION DATA

South Gas Station (SGS) Site

Travis AFB, California

WELL ID #	BOREHOLE TOTAL DEPTH (ft.bgs)	VEW SCREEN INTERVAL (ft.bgs)	CENTER of VMP SCREEN (ft.bgs)	FILTER PACK INTERVAL(s) (ft.bgs)	BENTONITE INTERVAL(s) (ft.bgs)	GROUT INTERVAL(s) (ft.bgs)
VEW-1	15.5	5.0 - 15.0	-	4.0 - 15.5	2.5 - 4.0	None
VEW-2	15.5	5.0 - 15.0	-	4.0 - 15.5	2.5 - 4.0	None
VMP-1	15.5	-	5.5	5.0 - 6.0	2.5 - 5.0	None
			13.5	13.0 - 14.0	6.0 - 13.0	
					14.0 - 15.5	
VMP-2	15.5	-	5.5	5.0 - 6.0	2.5 - 5.0	None
			13.5	13.0 - 14.0	6.0 - 13.0	
					14.0 - 15.5	
VMP-3	20.0	-	5.5	5.0 - 6.0	2.5 - 5.0	None
			13.5	13.0 - 14.0	6.0 - 13.0	
					14.0 - 20.0	

trvstab2.wk1



NOTE: SEE TABLE 1.2 FOR DETAILS

AS-BUILT VAPOR EXTRACTION WELL CONSTRUCTION DETAIL

SOUTH GAS STATION (SGS) SITE

TRAVIS AIR FORCE BASE
CALIFORNIA

ENGINEERING-SCIENCE, INC.

To prevent preferential air movement near the surface during pilot testing, a 1.5-foot thick annular bentonite seal was emplaced on the top of the filter pack. A 1-foot thick layer of filter pack material was placed on top of the bentonite seal to provide free drainage. The upper 1.5 feet of annular space was left vacant for ease of connecting subsurface piping for future pilot testing. The surface completion of each VEW consisted of a water-tight, traffic-proof, cast-iron well box (securable with hexbolts) emplaced within a 3-foot diameter concrete collar sloped away from the box for drainage. The top of the PVC well casing was cut to approximately one foot below the top of the box.

1.1.4 Vapor Monitoring Points

The two primary VMPs at the SGS Site (VMP-1 and VMP-2) were installed in a line parallel to and 7 feet north of the UST complex. VMP-1 was located 15 feet west of VEW-1, and VMP-2 was located 17 feet east of VEW-1. Both were in areas of soils having a noticeable fuel odor. The background VMP (VMP-3) was installed in uncontaminated soil approximately 320 feet west of VMP-1.

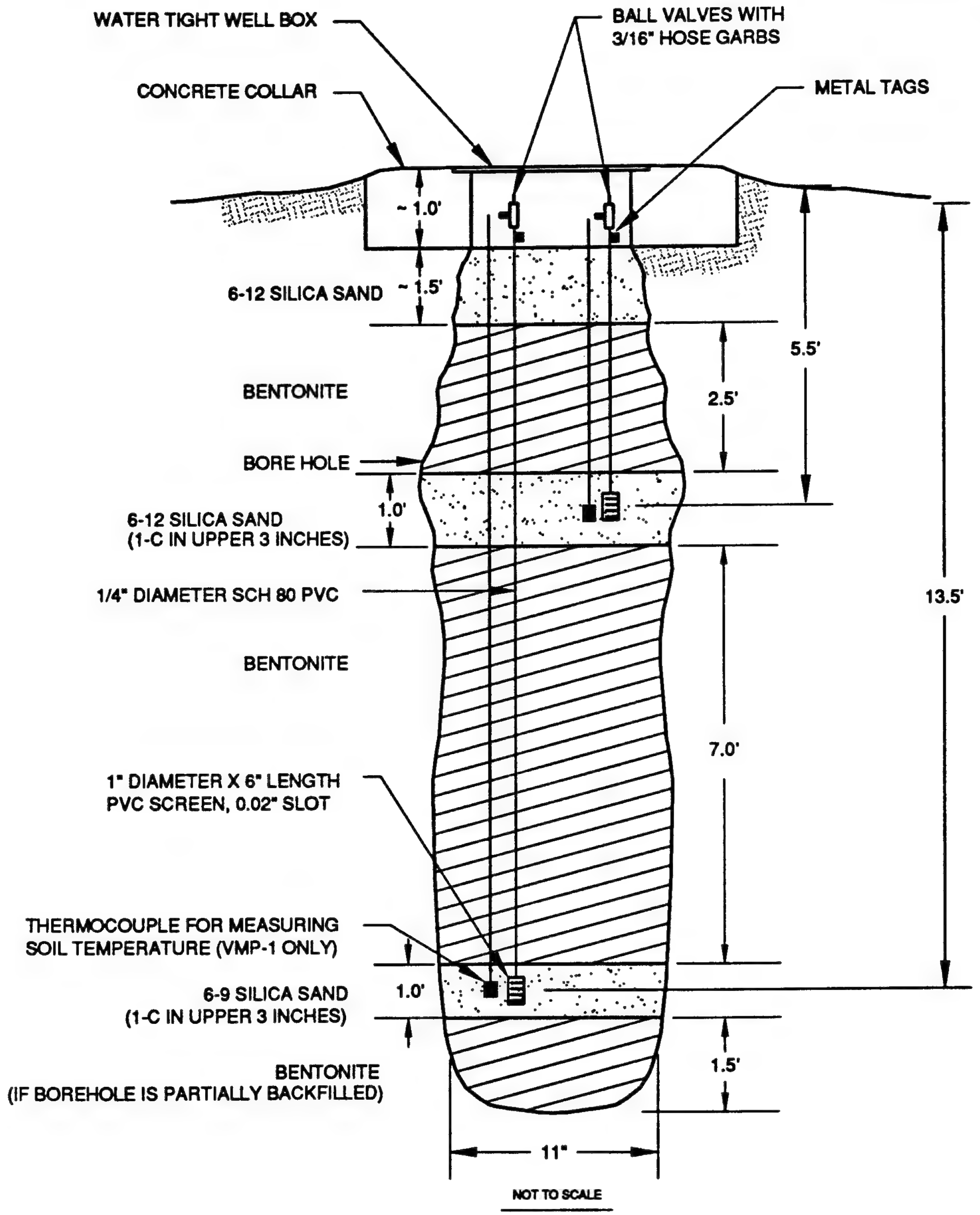
All VMPs were installed following procedures described in the protocol document (Hinchee et al., 1992). Table 1.2 shows construction data and Figure 1.4 shows construction details of the VMPs. All VMPs have identical construction details, with the exception of the background VMP, which was drilled to 20 feet bgs and therefore had a thicker interval of backfill at the bottom of the borehole. Each VMP was constructed using 0.25-inch ID, Schedule 80 PVC casing and 1-inch ID slotted screen intervals (0.020-inch slot size). Two casing strings/screens were installed in each VMP borehole at depths of 5.5 and 13.5 feet bgs to provide monitoring points at variable depths, soil types, and contamination levels.

Each of the screened intervals were 6 inches in length at the bottom of each individual PVC casing string, and were centered in a 1-foot thick layer of size 6-12 Lone Star sand (filter pack material) topped with a thin layer of size 1-C Lone Star sand. These filter pack intervals were sealed above and below with bentonite. A sampling valve was attached to the top of each casing string. In VMP-1, thermocouples were installed adjacent to both screens to allow measurement of soil temperature. The surface of each VMP was completed with a flush-mount well box similar to VEW surface completions.

1.1.5 Blower Units

A portable 3.0-horsepower (HP) Roots™ positive displacement blower unit was used for the initial pilot test, and was powered by an on site 230V, single-phase, 30A line from an above-ground power line and breaker provided by the base. During air extraction operations, the off-gas was treated by two granular activated carbon (GAC) cannisters positioned in series. Figure 1.5 shows the configuration, instrumentation, and specifications for this system used during the initial pilot test.

A fixed blower unit for the extended (one-year) pilot test has not been installed at the site. Section 4 of this report describes the configuration, instrumentation, specifications, and site layout for the proposed extended bioventing pilot testing system.



NOTE: SEE TABLE 1.2 FOR DETAILS

AS-BUILT VAPOR MONITORING POINT CONSTRUCTION DETAIL

SOUTH GAS STATION (SGS) SITE

TRAVIS AIR FORCE BASE
CALIFORNIA

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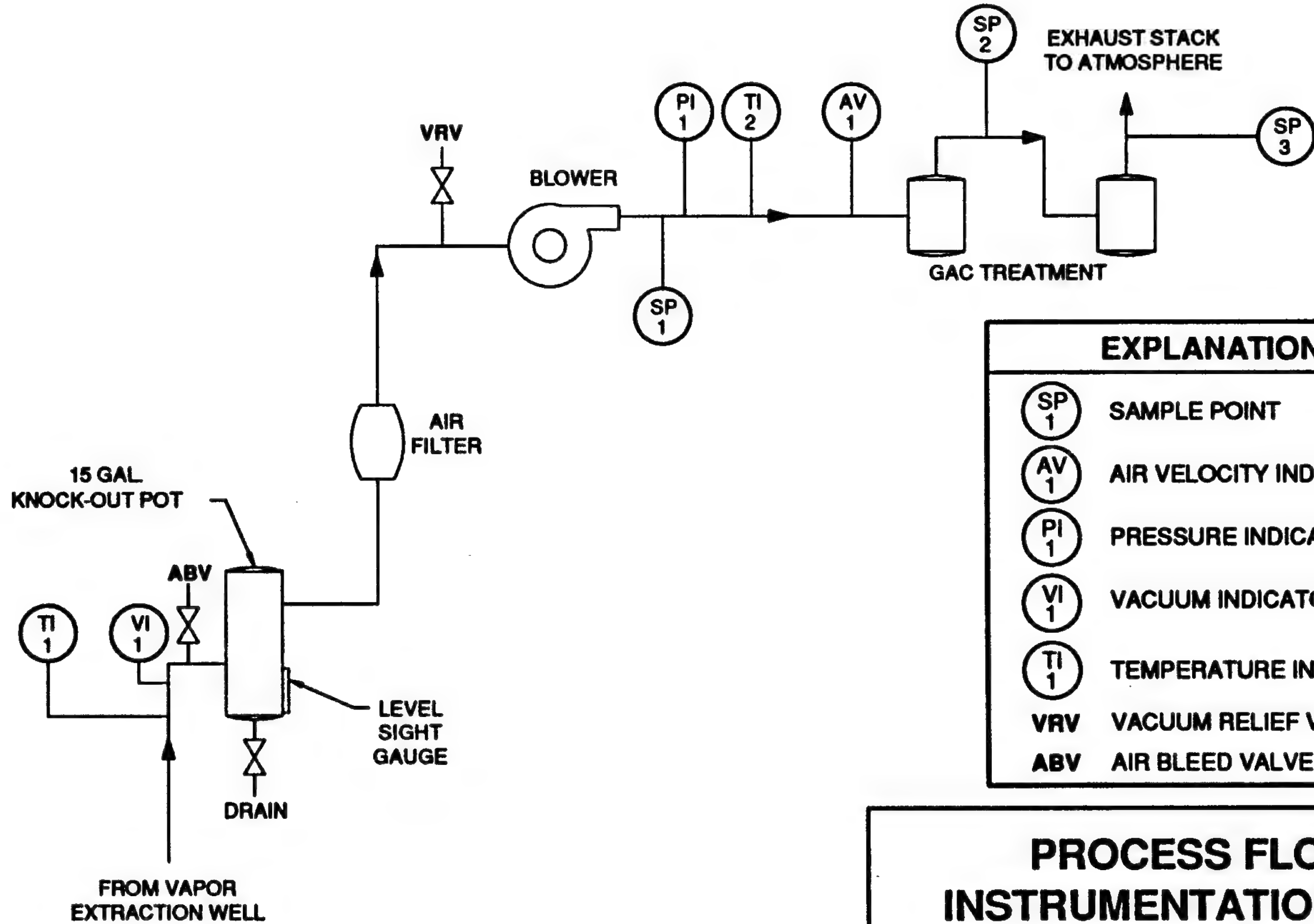
FIGURE 1.5



EXPLANATION

SP 1	SAMPLE POINT
AV 1	AIR VELOCITY INDICATOR
PI 1	PRESSURE INDICATOR
VI 1	VACUUM INDICATOR
TI 1	TEMPERATURE INDICATOR
VRV	VACUUM RELIEF VALVE
ABV	AIR BLEED VALVE

PROCESS FLOW AND INSTRUMENTATION DIAGRAM BIOVENTING PILOT TEST SOUTH GAS STATION

TRAVIS AIR FORCE BASE, CALIFORNIA

1.1.6 Exceptions to Test Protocol Document Procedures

Procedures described in the protocol document (Hinchee et al., 1992) related to pilot test design and construction were used with the following exceptions:

- Borehole diameters for the VMPs were 8 inches instead of 11 inches.
- Lone Star 6-12 sand was used for filter pack material in all VMPs and VEWs instead of 6-9 silica sand.
- Two wells were constructed as VEWs for the purpose of extended pilot testing design and implementation. One of the two VEWs was utilized as a VMP during the initial pilot test.
- Only two wells at the site were constructed as VMPs (excluding the background VMP).

1.2 Fuel Storage Area G (Site 1)

1.2.1 Introduction

Installation of one Vent Well (VW) and four Vapor Monitoring Points (VMPs) was conducted at Fuel Storage Area G (Site 1) between 16 and 18 February 1993. Locations of the VW and VMPs are shown on Figure 1.6. The background VMP (VMP-4) was located approximately 330 feet north of VW-1 near and outside the fence that surrounds the site. Borehole drilling services were provided by Gregg Drilling and Testing, Inc. of Pacheco, California. Soil sampling and well installation was directed on site by Mr. Henry Pietropaoli of the ES-Alameda office.

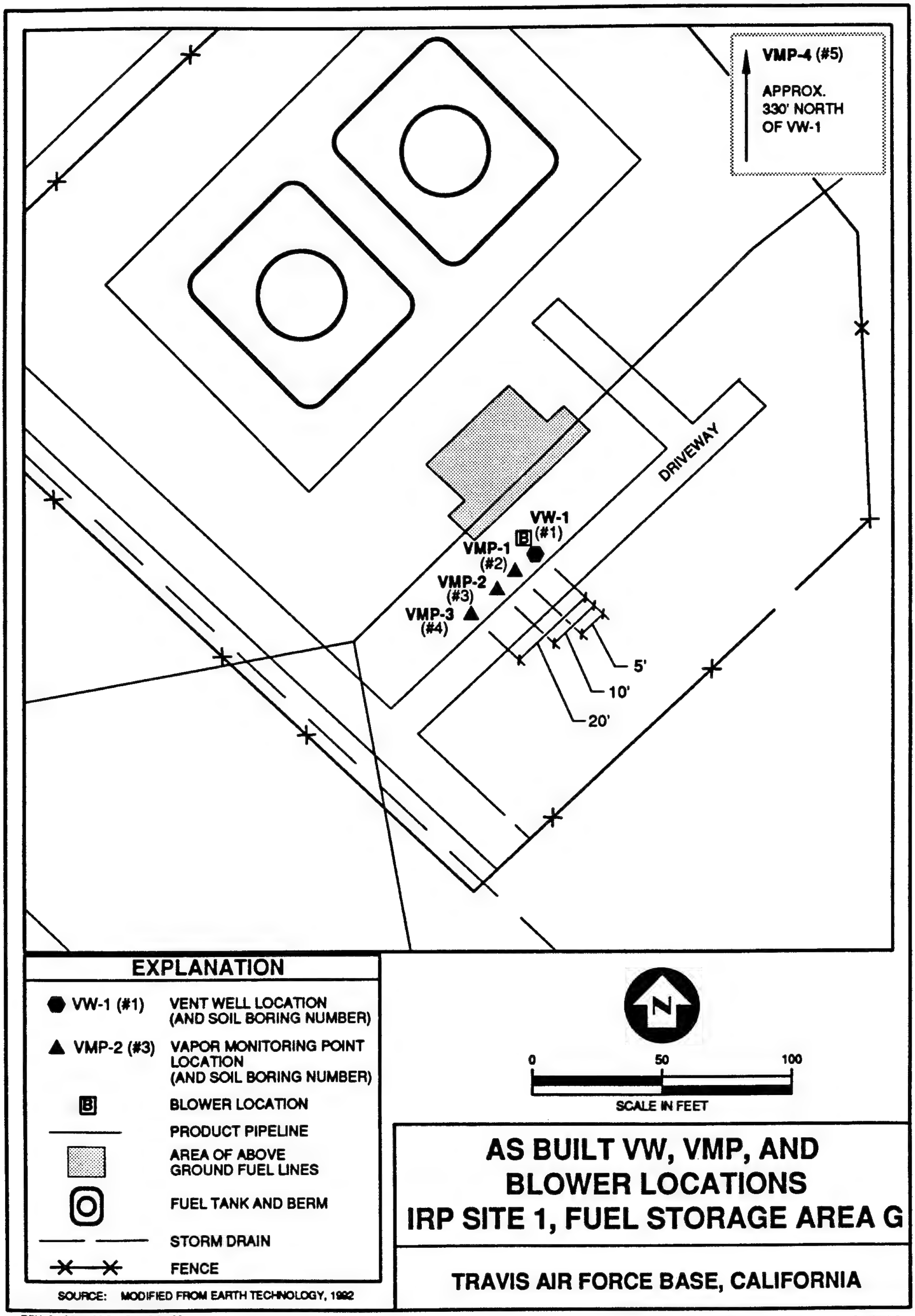
Five boreholes were drilled at the site and all were converted to a VW or VMPs. No boreholes were abandoned since contamination observed during drilling was at sufficient levels for VW and VMP siting, and clean soils were encountered throughout the background VMP borehole. Soil samples from split-spoon and/or continuous samplers were collected for field organic vapor analysis (OVA) to determine appropriate VW and VMP screened intervals and total depths. Both a total hydrocarbon vapor analyzer (THVA) and a photoionization detector (PID) were used to screen field samples. Soil samples were also collected for laboratory analysis. Table 1.3 summarizes pertinent borehole data.

1.2.2 Soil Profile

Figure 1.7 is a geologic cross-section of the pilot-test site using data from the VW and three VMPs (the background VMP is not shown). The interpreted soil profile is shown along with OVA readings, VW and VMP screened intervals, groundwater and floating product levels, and TRPH concentrations from laboratory analysis of soil samples. The soil boring logs are included in Appendix A.

Below the 6-inch layer of surface gravels, the observed soil profile down to about 2 feet bgs is a dark brown silty clay that is consistent throughout the investigated area. A predominantly greenish-brown clayey silt interval was found from approximately 2 feet to 7 feet bgs in all borings, and becomes progressively coarser-grained from southwest to

FIGURE 1.6



AS BUILT VW, VMP, AND BLOWER LOCATIONS IRP SITE 1, FUEL STORAGE AREA G

TRAVIS AIR FORCE BASE, CALIFORNIA

REV. 2 C250-39.DWG 08/31/93

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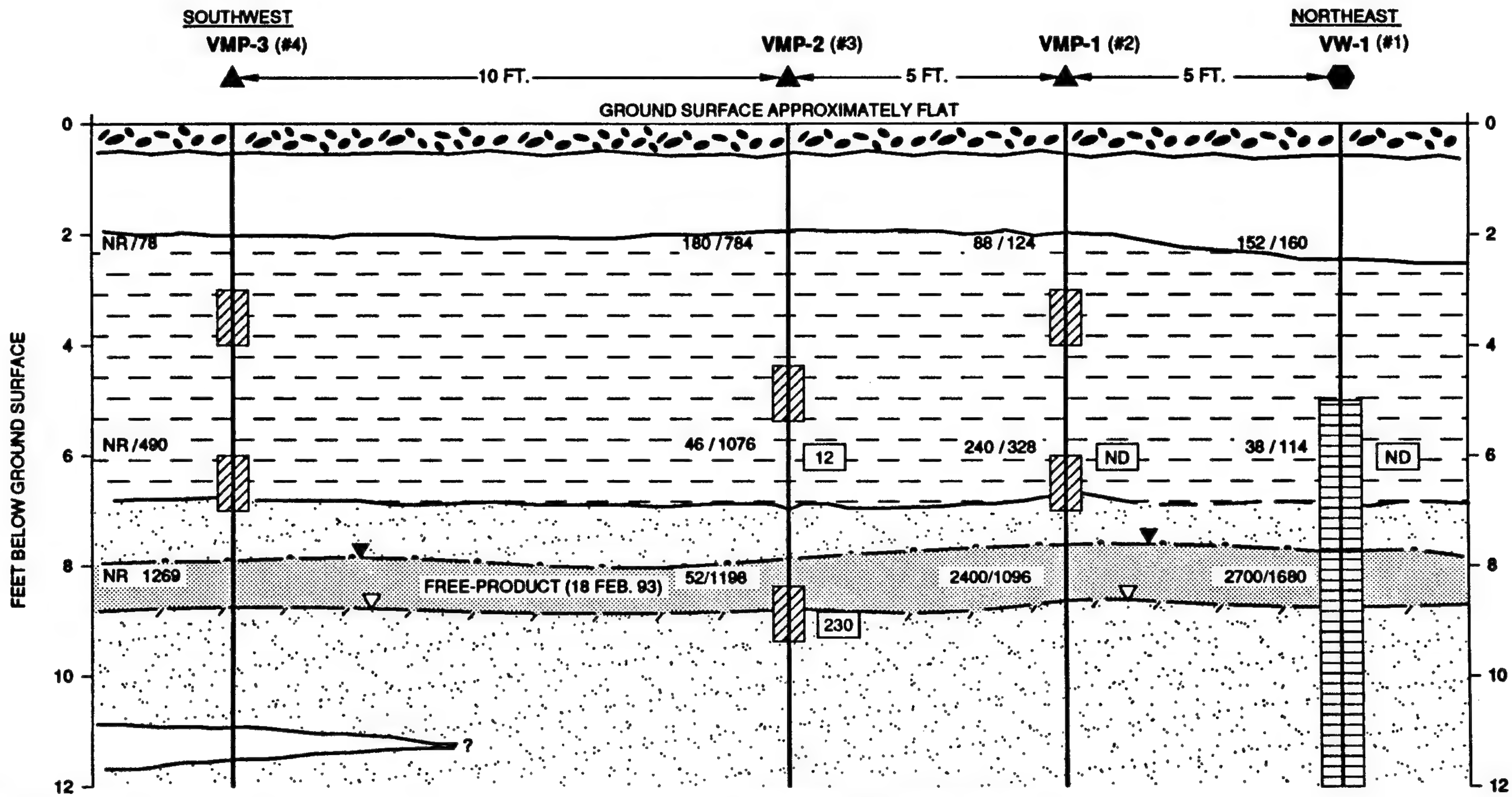
TABLE 1.3
BOREHOLE, SOIL SAMPLE, VMP/VW SUMMARY DATA
IRP Site 1: Fuel Storage Area G
Travis AFB, California

BOREHOLE ID #	BOREHOLE TOTAL DEPTH (ft. bgs)	SPLIT-SPOON INTERVAL (ft. bgs)	THVA/PID HEADSPACE READINGS (PPM)	SOIL SAMPLE ID #	START DATE	COMPLETION DATE	COMPLETION DESIGNATION
1	12.0	2.0 - 3.5	152/160	-	16Feb93	18Feb93	VW-1
		5.0 - 6.5	38/114	TR1-VEW1-6			
		8.0 - 9.5	2700/1680	-			
2	12.0	2.0 - 3.5	88/124	-	16Feb93	18Feb93	VMP-1
		5.0 - 6.5	240/328	TR1-VMP1-6			
		8.0 - 9.5	2400/1680	-			
3	12.0	2.0 - 3.5	180/784	-	16Feb93	18Feb93	VMP-2
		5.0 - 6.5	46/1076	TR1-VMP2-6			
		8.0 - 9.5	52/1198	TR1-VMP2-9			
4	12.0	2.0 - 3.5	NR/78	-	16Feb93	18Feb93	VMP-3
		5.0 - 6.5	NR/490	-			
		8.0 - 9.5	NR/1269	-			
5	12.0	2.0 - 3.5	0/145	-	17Feb93	18Feb93	VMP-4
		5.0 - 6.5	0/24	TR1-VMP4-6			
		8.5 - 10.0	0/11	-			
		10.0 - 11.5	2/19	-			

NOTE: NR - Not Recorded

trvstab3.WK1

FIGURE 1.7



EXPLANATION

VMP-2 (#3) — VAPOR MONITORING POINT (and Soil Boring Number)

VW-1 (#1) — VENT WELL (and Soil Boring Number)

120/435 — FIELD OVA (SOIL) DATA: THVA/PID (ppm)

TOP OF FREE-PRODUCT LAYER (18 FEB 93)

TOP OF GROUNDWATER (18 FEB 93)

14 — TRPH CONCENTRATION IN SOIL (mg/kg)

GEOLOGIC CONTACT

VMP FILTER PACK (SCREEN) INTERVAL

VW SCREENED INTERVAL

SCALES (No Vertical Exaggeration)

FEET 0 2

FEET 0 2

LITHOLOGIC DESCRIPTION

GRAVEL

SAND, SILTY/CLAYEY SAND

CLAYEY SILT

CLAY, SILTY CLAY

GEOLOGIC CROSS-SECTION

IRP SITE 1
FUEL STORAGE AREA G

TRAVIS AIR FORCE BASE
CALIFORNIA

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northeast (silty clay to a clayey silt/fine sand). This interval exhibited a noticeable fuel odor in all boreholes.

The base of the observed soil profile, in the lower 5 feet of each boring, is a fine- to medium-grained sand with some silt and clay. This sand had a blue-green/gray discoloration in part and had a noticeable fuel odor throughout. The thickness of this interval is unknown, since the borings were advanced to only 12 feet bgs. However, the boring for S1-3, a boring advanced during a previous study (Earth Technology 1992), encountered this sand down to approximately 20 feet bgs. The cross-section presented in the Bioventing Test Work Plan (Part I) based on borings from previous studies indicate this sand interval to vary in thickness from 10 to 20 feet.

Groundwater and floating product was encountered in all four borings at the site. Thickness estimates of the floating product ranged from 0.6 to 1.0 feet (VW-1 and VMP-3 respectively). Estimates of depth to floating product ranged from 7.7 to 7.9 feet bgs, and depth to groundwater ranged from 8.2 to 8.8 feet bgs. These depths to floating product were much shallower than those measured during the November 1991 site investigation (Earth Technology 1992), when depth to floating product in boring SB-8 was approximately 12 feet bgs. This apparent rise was most likely due to the seasonal fluctuations in the local water table.

The soils encountered in the background VMP (VMP-4) located approximately 330 feet north of VW-1 were very similar to soils observed in borings at the site. The VMP-4 soils did not exhibit any staining or odor, floating product was not encountered, and the sand interval and groundwater were encountered in VMP-4 at a deeper depth (both at 11.5 feet bgs) than observed in borings at the site.

1.2.3 Air Injection Vent Well

One air injection VW (VW-1) was installed in a location of noticeable fuel odor following procedures described in the protocol document (Hinchee et al., 1992). VW-1 was installed 2 feet northwest of the paved driveway and 25 feet southwest of the above ground fuel lines. Table 1.4 shows construction data and Figure 1.8 shows construction details for VW-1.

VW-1 was constructed using 4-inch ID, Schedule 40 PVC casing and slotted screen (0.040-inch slot size). The annular space adjacent to the screen was filled with size 6-12 Lone Star sand (filter pack material) from the base of the borehole to 1 foot above the top of the screen. A small amount of size 1-C Lone Star sand was added to the top of this interval to inhibit penetration of the overlying bentonite seal material into the filter pack interval.

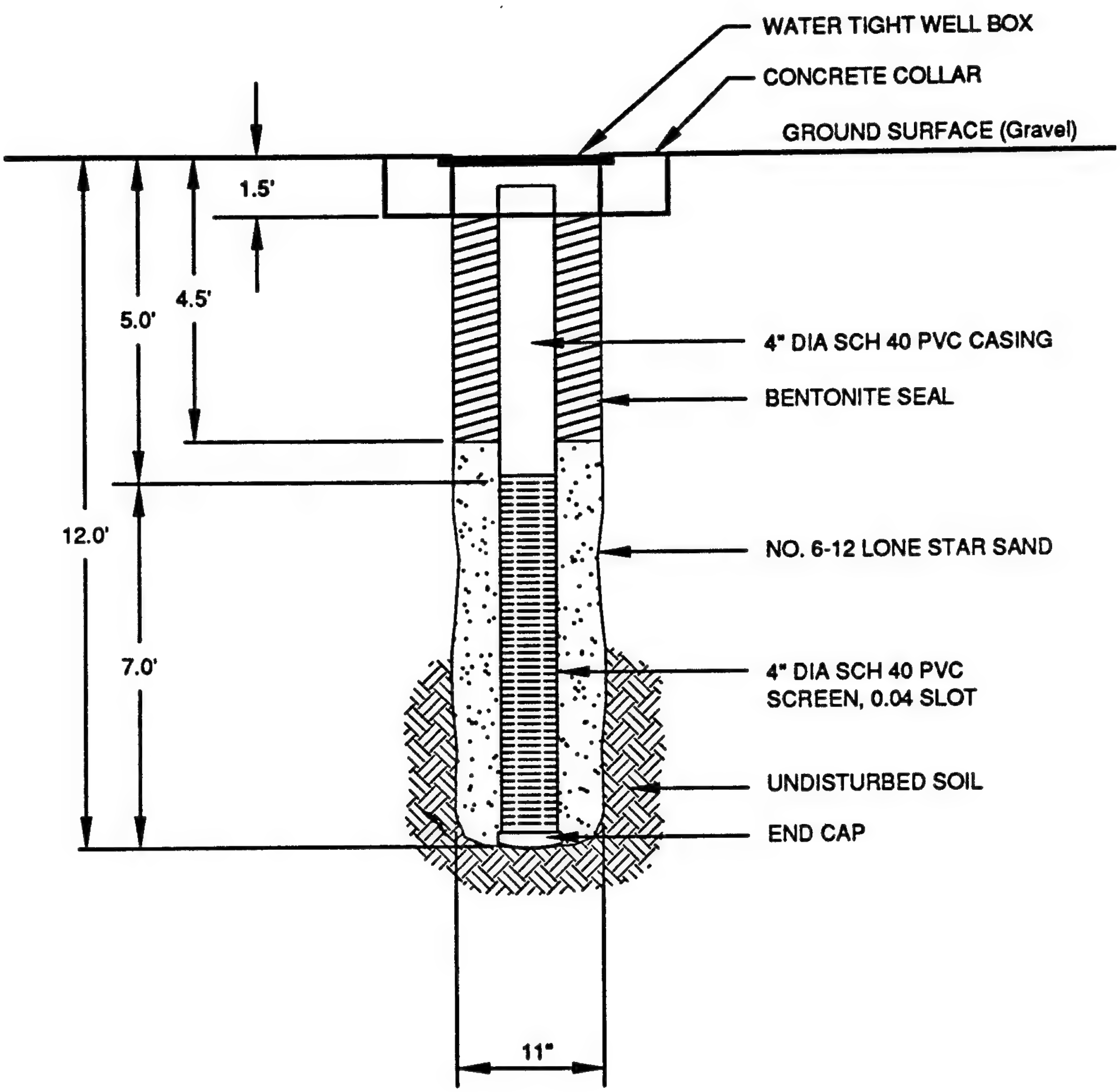
To prevent preferential air movement near the surface during pilot testing, a 3-foot thick annular bentonite seal was emplaced on top of the filter pack. The upper 1.5 feet of annular space was left vacant for ease of connecting subsurface piping for pilot testing and possible future full-scale remediation system implementation. The surface completion of the VW consisted of a water-tight, traffic-proof, cast-iron well box (securable with hexbolts) emplaced within a 3-foot diameter concrete collar sloped away from the box for drainage. The top of the PVC well casing was cut to approximately one

TABLE 1.4
VMP/VW CONSTRUCTION DATA
IRP Site 1: Fuel Storage Area G
Travis AFB, California

WELL ID #	BOREHOLE TOTAL DEPTH (ft.bgs)	VW SCREEN INTERVAL (ft.bgs)	CENTER of VMP SCREEN (ft.bgs)	FILTER PACK INTERVAL(s) (ft.bgs)	BENTONITE INTERVAL(s) (ft.bgs)	GROUT INTERVAL(s) (ft.bgs)
VW-1	12.0	5.0 - 12.0	-	4.5 - 12.0	1.5 - 4.5	None
VMP-1	12.0	-	3.5	3.0 - 4.0	1.0 - 3.0	None
			6.5	6.0 - 7.0	4.0 - 6.0	
					7.0 - 12.0	
VMP-2	12.0	-	5.0	4.5 - 5.5	1.0 - 4.5	None
			9.0	8.5 - 9.5	5.5 - 8.5	
					9.5 - 12.0	
VMP-3	12.0	-	3.5	3.0 - 4.0	1.0 - 3.0	None
			6.5	6.0 - 7.0	4.0 - 6.0	
					7.0 - 12.0	
VMP-4	12.0	-	3.5	3.0 - 4.0	1.0 - 3.0	None
			6.5	6.0 - 7.0	4.0 - 6.0	
					7.0 - 12.0	

trvstab4.wk1

FIGURE 1.8



NOT TO SCALE

NOTE: SEE TABLE 1.4 FOR DETAILS

AS-BUILT INJECTION VENT WELL CONSTRUCTION DETAIL

IRP SITE 1; FUEL STORAGE AREA G

TRAVIS AIR FORCE BASE CALIFORNIA

REV. 0 C250-41.DWG 05/17/93

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foot below the top of the box. The well casing was connected directly to the portable blower unit above ground for the initial pilot test and then to the fixed blower unit located adjacent to the well for the extended pilot test.

1.2.4 Vapor Monitoring Points

The three primary VMPs were installed in a line parallel to and 2 feet northwest of the paved driveway. VMP-1, VMP-2, and VMP-3 were located 5, 10, and 20 feet southwest of VW-1, respectively. This line of wells is near the location of former soil boring SB-8 from which soil-sample analysis indicated Total Petroleum Hydrocarbons as gasoline (TPH-g) at the highest concentrations found at the site (3,800 mg/kg TPH-g at 10 feet bgs; see Part I). The background VMP (VMP-4) was installed approximately 330 feet north of VW-1.

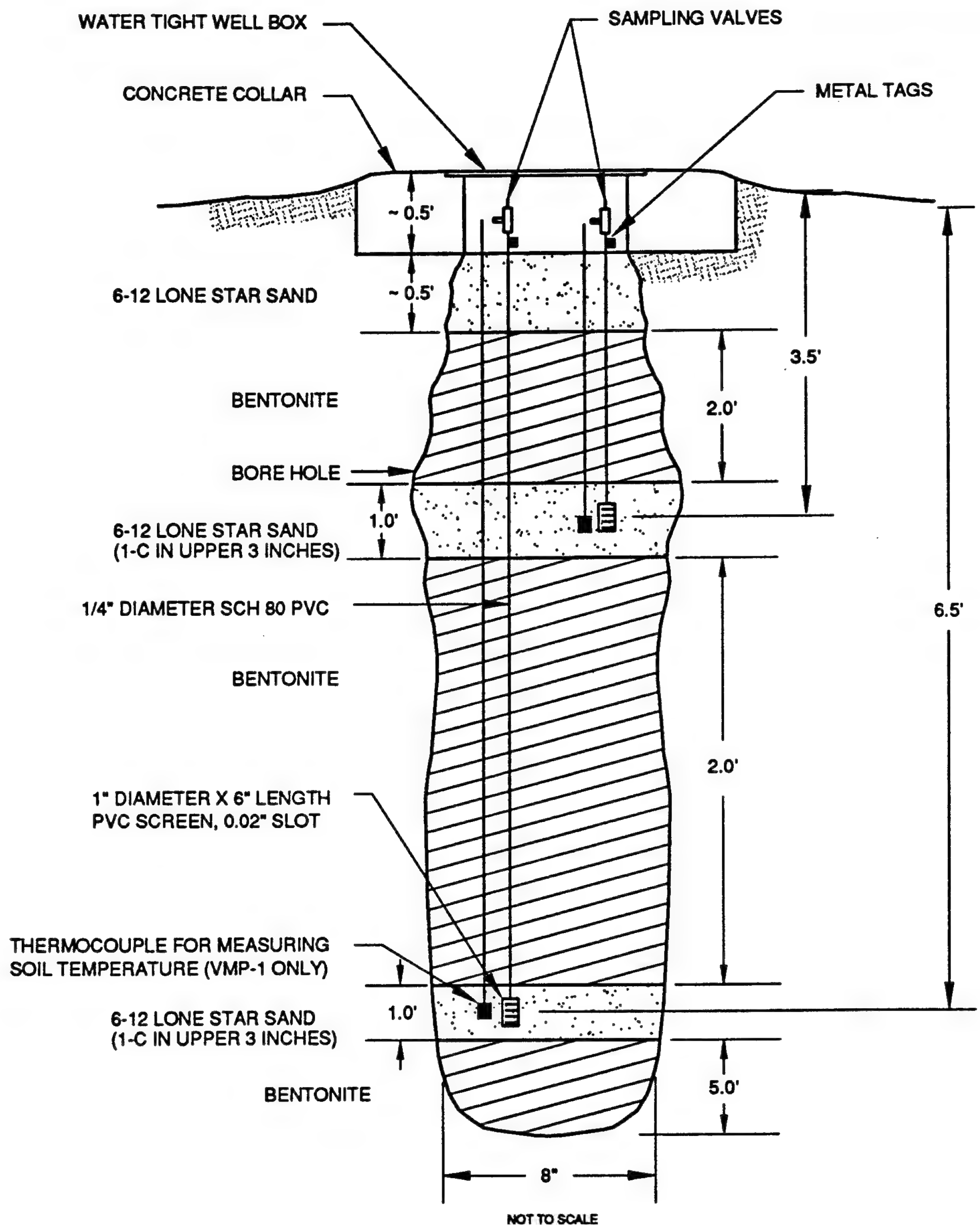
All VMPs were installed following procedures described in the protocol document (Hinchee et al., 1992). Table 1.4 shows construction data and Figure 1.9 shows construction details of the VMPs. Three of the VMPs have nearly identical construction details, with the exception of VMP-2 which has screened intervals at different depths. Each VMP was constructed using 0.25-inch ID, Schedule 80 PVC casing and 1-inch ID slotted screen intervals (0.020-inch slot size). Two casing strings/screens were installed in each VMP borehole at depths of 3.5 and 6.5 feet bgs (5 and 9 feet bgs in VMP-2) to provide monitoring points at variable depths, soil types, and contamination levels.

Each of the screened intervals were 6 inches in length at the bottom of each individual PVC casing string, and were centered in a 1-foot thick layer of size 6-12 Lone Star sand (filter pack material) topped with a thin layer of size 1-C Lone Star sand. These filter pack intervals were sealed above and below with bentonite. A sampling valve was attached to the top of each casing string. In VMP-1, thermocouples were installed adjacent to both screens to allow measurement of soil temperature. The surface of each VMP was completed with a flush-mount well box similar to the VW surface completion.

1.2.5 Blower Units

A portable 3.0-horsepower Roots™ positive displacement blower unit was used for the initial pilot test, and was powered by an on site 230V, single-phase, 30A line from an above ground power line and breaker provided by the base. A fixed 1.0-HP Gast™ regenerative blower unit (R-4 blower) was installed on 24 June 1993 for the extended pilot test. This unit is powered by the same line used for the portable unit. Proper explosion-proofing measures were implemented for both the portable and fixed units.

At the time of installation, the fixed blower unit was injecting approximately 14 standard cubic feet per minute (scfm) for the extended pilot test. Figure 1.10 shows the configuration, instrumentation, and specifications for this system. ES personnel provided an operations and maintenance (O&M) data collection sheet and blower maintenance manual to base personnel. A copy of the data collection sheet and manual is provided in Appendix B.



NOTE: SEE TABLE 1.4 FOR DETAILS

SCREENS IN VMP-2 WERE INSTALLED AT 5.0 FT. AND 9.0 FT. BGS.

AS-BUILT VAPOR MONITORING POINT CONSTRUCTION DETAIL

IRP SITE 1: FUEL STORAGE AREA G

TRAVIS AIR FORCE BASE CALIFORNIA

REV. 0 C246-11.DWG 05/14/93

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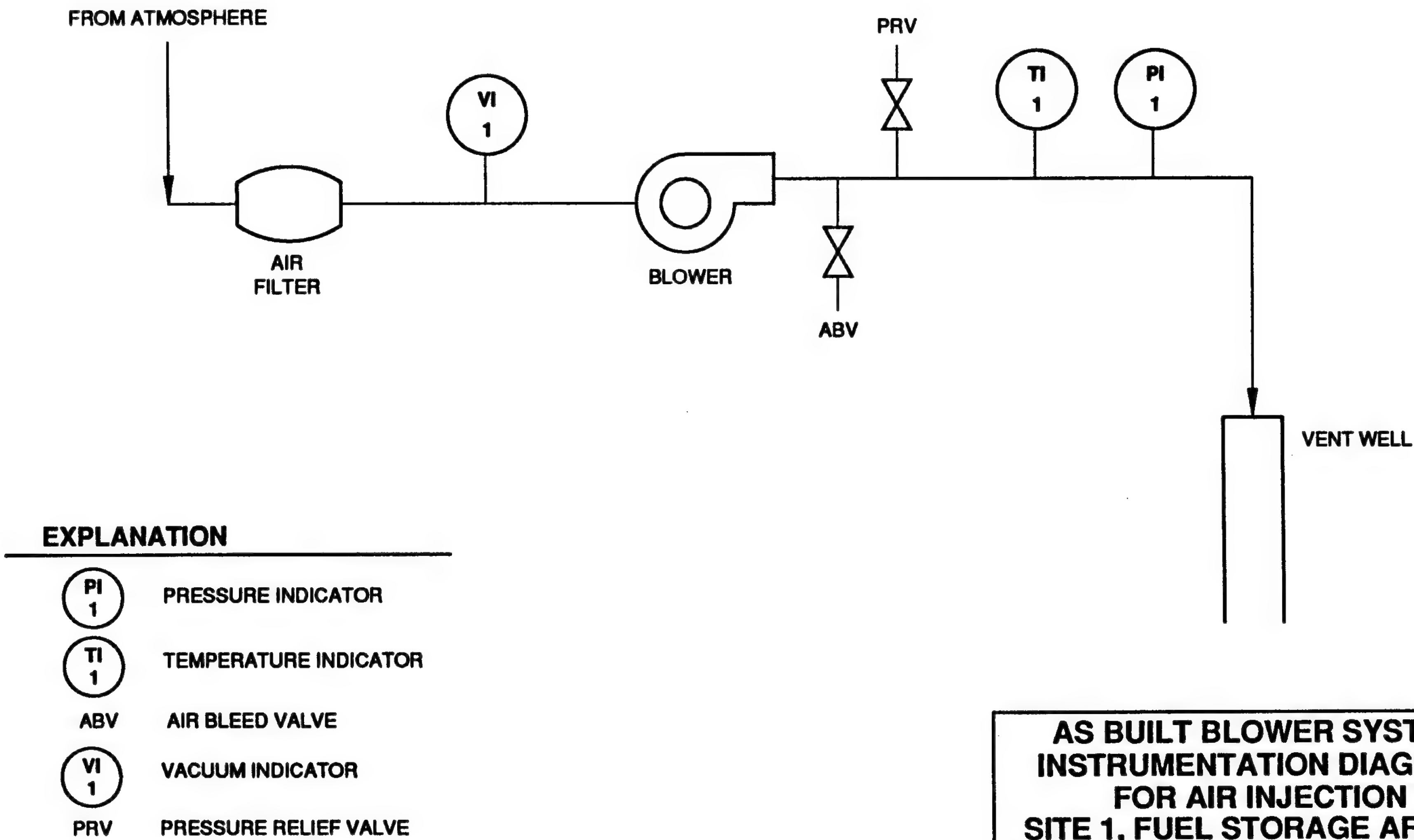
FIGURE 1.10



AS BUILT BLOWER SYSTEM INSTRUMENTATION DIAGRAM FOR AIR INJECTION SITE 1, FUEL STORAGE AREA G

TRAVIS AIR FORCE BASE, CALIFORNIA

1.2.6 Exceptions to Test Protocol Document Procedures

Procedures described in the protocol document (Hinchee et al., 1992) related to pilot test design and construction were used with the following exceptions:

- Borehole diameters for the VMPs were 8 inches instead of 11 inches.
- Lone Star 6-12 sand was used for filter pack material in all VMPs and the VW instead of 6-9 silica sand.

2.0 PILOT TEST SOIL AND SOIL-GAS SAMPLING RESULTS

2.1 South Gas Station (SGS) Site

2.1.1 Soil Sample Field Analysis

Contaminated soils were identified based on field observations such as visual appearance, odor, and OVA readings. OVA readings were monitored using both a photoionization detector (PID) and a total hydrocarbon vapor analyzer (THVA) on all soil samples in order to estimate the relative amount and extent of soil contamination detectable by such devices. OVA readings using the PID were generally higher than the THVA readings (see Table 1.1). However, where the THVA readings were above 1,000 ppm, the PID and THVA readings were more similar.

2.1.2 Soil Sample Laboratory Analysis

Soil samples for laboratory analysis were collected using a hammer-driven split-spoon sampler lined with brass sleeves. The samples were preserved in the brass sleeves and capped with Teflon™ tape and plastic end caps. Selection of soil samples for laboratory analysis was based on field OVA readings, visual appearance, and odor. Samples from VEW-1, VMP-1, and VMP-2 were collected from depths of 15 feet bgs (see Table 1.1).

The selected soil samples were hand-delivered to the ES-Berkeley Laboratory (ESBL) for chemical and physical analysis. Chain-of-custody forms are included in Appendix C. Analytes were: total recoverable petroleum hydrocarbons (TRPH); benzene, toluene, ethylbenzene, and total xylenes (BTEX); iron; alkalinity; pH; total Kjeldahl nitrogen (TKN); phosphates; moisture; and grain size distribution. Samples to be analyzed for TKN, phosphates, and grain size distribution were transferred to Sequoia Analytical in Redwood City, California. The results of all analyses are summarized in Table 2.1. The TRPH concentrations are also included on the geological cross section (Figure 1.2).

2.1.3 Soil-Gas Sample Laboratory Analysis

Subsurface soil-gas samples were also collected for laboratory analysis in Summa® cannisters. These samples were collected from VEW-1, and from the screen at 14 feet bgs in VMP-2 after purging the individual casings of at least one volume of air. In addition, a soil-gas sample was collected at VEW-1 near the end of the air permeability test (sample "PP") in order to compare TVH and BTEX concentrations before and during extraction to evaluate potential air emissions during long-term pilot testing. The soil-gas samples were shipped to Air Toxics, Ltd. in Rancho Cordova, California for analysis of total volatile hydrocarbons as gasoline (TVH-g) and BTEX. Chain-of-custody Forms are included in Appendix C. The results of these analyses are summarized in Table 2.1.

Additional soil-gas monitoring with THVA and O_2/CO_2 meters was performed at VEW-1 and at various points in the surface off-gas treatment system during the air permeability test to evaluate effectiveness of the off-gas treatment. Details of monitoring procedures and results are discussed in Section 3.

TABLE 2.1
SOIL and SOIL GAS ANALYTICAL RESULTS
South Gas Station (SGS) Site
Travis AFB, California

ANALYTE	UNITS	SAMPLE LOCATION – DEPTH (well number and feet below ground surface)		
Soil Hydrocarbons:		**VEW1–15**	**VMP1–15**	**VMP2–15**
TRPH	(mg/kg)	30	14	16
Benzene	(mg/kg)	3.8	2.5	5.6
Toluene	(mg/kg)	5.7	5.0	15.0
Ethylbenzene	(mg/kg)	2.9	8.4	10.0
Xylenes	(mg/kg)	16.0	53.0	47.0
Soil Inorganics:		**VEW1–15**	**VMP1–15**	**VMP2–15**
Iron	(mg/kg dry wt.)	20,800	29,000	16,400
Alkalinity	(mg/kg as $CaCO_3$)	140	60	150
pH	(units)	7.7	8.2	7.8
TKN	(mg/kg dry wt.)	140	95	390
Phosphates	(mg/kg dry wt.)	360	330	200
Soil Physical Parameters:		**VEW1–15**	**VMP1–15**	**VMP2–15**
Moisture	(% wt.)	18.7	12.3	21.0
Gravel	(% wt.)	0	0	0
Sand	(% wt.)	63	57	62
Silt	(% wt.)	27	29	26
Clay	(% wt.)	10	14	12
Soil Gas Hydrocarbons:		**VEW1**	**VMP2–14**	**VEW1 (PP)**
TVH–g	(ppmv)	140,000	150,000	35,000
Benzene	(ppmv)	1,800	1,500	420
Toluene	(ppmv)	950	1,300	460
Ethylbenzene	(ppmv)	46	75	42
Xylenes	(ppmv)	160	320	170

NOTES:
TRPH – Total recoverable petroleum hydrocarbons
TVH – Total volatile hydrocarbons
TVH–g – Total volatile hydrocarbons as gasoline.
TKN – Total Kjeldahl nitrogen
ppmv – Parts per million, volume per volume

$CaCO_3$ – Calcium carbonate
mg/kg – milligrams per kilogram
ND – Not detected
NA – Not Analyzed

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2.1.4 Field QA/QC Results

No QA/QC soil samples (field duplicates) were collected during sampling activities at the test site.

2.1.5 Subsurface Contamination

The extent of the soil hydrocarbon contamination at the site remains unknown. All boreholes drilled encountered evidence of hydrocarbon contamination. OVA readings greater than 1,000 ppm were measured in all boreholes. The highest OVA readings in each boring were generally recorded in the sand zone, approximately 15 feet bgs (Figure 1.2). A fuel odor was noticed throughout the observed soil profile in all boreholes, with soils in the VMP-2 borehole having a less-noticeable odor. Some green to blue-green discoloration was reported throughout the observed soil profile in all boreholes at the site, except VMP-2.

Laboratory analysis of soil and soil-gas samples documented hydrocarbon contamination in all wells. TRPH was detected in all soil samples at relatively low concentrations because the TRPH laboratory test range does not include gasoline. However, BTEX was detected in significant concentrations in all soil and soil-gas samples. Soil-gas samples VEW-1 and VMP2-14 had 140,000 and 150,000 ppmv TVH-g, respectively. Therefore, those laboratory analyses which are specific to the more volatile fuel hydrocarbon components found in gasoline (TVH-g and BTEX) showed the highest relative concentrations and are more indicative of actual contamination.

2.1.6 Exceptions To Test Protocol Document Procedures

Procedures described in the protocol document (Hinchee et al., 1992) related to soil and soil-gas sampling were used with the following exceptions:

- Soil samples were screened in the field (OVA readings) using both a THVA and a PID in order to compare data from both devices.
- A soil-gas sample from the furthest VMP from the vent well was not collected because this monitoring point was constructed as a vapor extraction well (VEW-2) instead of discrete vapor monitoring points. Therefore, the sample analysis would represent soil-gas concentrations over several vertical feet instead of at a discrete depth.
- Soil-gas samples were analyzed for TVH-g due to the known fuel type at the site.
- An extra soil-gas sample was collected at VEW-1 ("PP") during the air permeability test to evaluate potential air emissions during long-term pilot testing.

2.2 Fuel Storage Area G (Site 1)

2.2.1 Soil Sample Field Analysis

Contaminated soils were identified based on field observations such as visual appearance, odor, and OVA readings. OVA readings were monitored using both a photoionization detector (PID) and a total hydrocarbon vapor analyzer (THVA) on all soil samples (except those in VMP-3 due to THVA equipment trouble) in order to

estimate the relative amount and extent of soil contamination detectable by such devices. OVA readings using the PID were generally higher than the THVA readings (see Table 1.3). However, where THVA readings were above 1,000 ppm, PID and THVA readings were more similar.

2.2.2 Soil Sample Laboratory Analysis

Soil samples for laboratory analysis were collected by using a hammer-driven split-spoon sampler lined with brass sleeves. The samples were preserved in the brass sleeves and capped with Teflon™ tape and plastic end caps. Selection of soil samples for laboratory analysis was based on field OVA readings, visual appearance, and odor. Samples from VW-1, VMP-1, VMP-2, and VMP-4 were collected from depths of 6 feet bgs, with an additional sample collected at 9 feet bgs in VMP-2 (see Table 1.3). The deeper sample from VMP-2 was collected slightly below the free-product/water interface.

The selected soil samples were hand-delivered to the ES-Berkeley Laboratory (ESBL) for chemical and physical analysis. Chain-of-custody forms are included in Appendix C. Analytes for all soil samples, except the 9-foot bgs sample from VMP-2 and the background soil sample collected from VMP-4, were: TRPH; BTEX; iron; alkalinity; pH; total Kjeldahl nitrogen (TKN); phosphates; moisture; and grain size distribution. Analytes for the 9-foot bgs sample from VMP-2 were only TRPH and BTEX. The background soil sample collected from VMP-4 at 6 feet bgs was only analyzed for TKN so that baseline soil nutrient conditions could be quantified. Samples to be analyzed for TKN, phosphates, and grain size distribution were transferred to Sequoia Analytical in Redwood City, California. The results of all analyses are summarized in Table 2.2. The TRPH concentrations are also included on the geological cross section (Figure 1.7).

2.2.3 Soil-Gas Sample Laboratory Analysis

Subsurface soil-gas samples were collected for laboratory analysis in Summa® cannisters. These samples were collected from the Vent Well (VW-1), and from the screened intervals at 6.5 feet bgs in VMP-1 and VMP-3 after purging the individual casings of at least one volume of air. The soil-gas samples were shipped to Air Toxics, Ltd. in Rancho Cordova, California for analysis of total volatile hydrocarbons as jet fuel (TVH-jf) and BTEX. Chain-of-custody forms are included in Appendix C. The results of these analyses are summarized in Table 2.2.

Additional surface soil-gas samples were collected before and during the air injection for laboratory analysis to determine potential emissions of TVH and BTEX to the atmosphere resulting from air injection during the pilot test. Two samples were collected at a surface location 6.5 feet to the northwest of VW-1. One sample was collected prior to the start of air injection (sample BKT-1) and one sample 2 hours after the start of air injection (sample BKT-2). The results of these analyses are shown in Table 2.2 and discussed in Section 3.2.5.

TABLE 2.2
SOIL and SOIL GAS ANALYTICAL RESULTS
Fuel Storage Area G (Site 1)
Travis AFB, California

ANALYTE	UNITS	SAMPLE LOCATION – DEPTH (well number and feet below ground surface)				
Soil Hydrocarbons:		VW1–6	VMP1–6	VMP2–6	VMP2–9	VMP4–6
TRPH	(mg/kg)	ND	ND	12	230	NA
Benzene	(mg/kg)	0.022	0.026	0.38	ND	NA
Toluene	(mg/kg)	0.030	0.027	2.0	ND	NA
Ethylbenzene	(mg/kg)	0.012	0.013	1.5	35.0	NA
Xylenes	(mg/kg)	0.040	0.042	5.8	45.0	NA
Soil Inorganics:		VW1–6	VMP1–6	VMP2–6	VMP2–9	VMP4–6
Iron	(mg/kg dry wt.)	29,500	32,000	23,800	NA	NA
Alkalinity	(mg/kg as $CaCO_3$)	76	150	140	NA	NA
pH	(units)	7.3	7.5	7.5	NA	NA
TKN	(mg/kg dry wt.)	82	30	130	NA	74
Phosphates	(mg/kg dry wt.)	220	240	200	NA	NA
Soil Physical Parameters:		VW1–6	VMP1–6	VMP2–6	VMP2–9	VMP4–6
Moisture	(% wt.)	14.8	16.4	14.3	NA	NA
Gravel	(% wt.)	0	0	0	NA	NA
Sand	(% wt.)	22	32	37	NA	NA
Silt	(% wt.)	50	42	40	NA	NA
Clay	(% wt.)	28	26	23	NA	NA
Soil Gas Hydrocarbons:		VW1	VMP1–6.5	VMP3–6.5		
TVH–jf	(ppmv)	110,000	120,000	110,000		
Benzene	(ppmv)	1,400	1,500	1,000		
Toluene	(ppmv)	670	800	180		
Ethylbenzene	(ppmv)	250	30	23		
Xylenes	(ppmv)	120	120	51		
Soil Gas Hydrocarbons (at surface):		BKT–1	BKT–2			
TVH–jf	(ppmv)	7.3	1.9			
Benzene	(ppmv)	0.007	ND			
Toluene	(ppmv)	0.007	ND			
Ethylbenzene	(ppmv)	ND	ND			
Xylenes	(ppmv)	0.010	ND			

NOTES:
TRPH – Total recoverable petroleum hydrocarbons
TVH – Total volatile hydrocarbons
TVH–jf – Total volatile hydrocarbons as jet fuel
TKN – Total Kjeldahl nitrogen
ppmv – parts per million by volume

$CaCO_3$ – Calcium carbonate
mg/kg – milligrams per kilogram
ND – Not detected
NA – Not Analyzed

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2.2.4 Field QA/QC Results

No QA/QC soil samples (field duplicates) were collected during sampling activities at the test site.

2.2.5 Subsurface Contamination

The extent of the hydrocarbon contamination at the site remains unknown. All boreholes drilled at the site encountered evidence of hydrocarbon contamination. Floating product was encountered at depths of 7.7 to 7.9 feet below ground surface and thickness estimates of the product ranged from 0.6 to 1.0 feet. OVA readings greater than 1,000 ppm were measured in all boreholes. The highest OVA readings in each boring were generally recorded in the sand zone contaminated with floating product (Figure 1.7). A fuel odor was noticed throughout the observed soil profile in all boreholes at all depths.

Laboratory analysis of soil and soil-gas samples documented hydrocarbon contamination in all wells. TRPH was detected only in soil samples from VMP-2 and at relatively low concentrations, in part because the TRPH laboratory test analyzes for only a fraction of the range of jet fuel. But perhaps more important is the observation that previous site investigations (Earth Technology 1992) documented the highest TPH concentrations generally between 10 and 12 feet bgs which was above the water table at that time. During this present investigation, no vadose-zone soil samples were able to be collected below about 7 feet bgs due to the relatively high water table observed. BTEX components were detected in significant concentrations only in soil samples from VMP-2, particularly near the product-water interface. However, all soil-gas samples had significantly high TVH-jf concentrations, indicating that the vadose zone has significant fuel hydrocarbon contamination.

2.2.6 Exceptions To Test Protocol Document Procedures

Procedures described in the protocol document (Hinchee et al., 1992) related to soil and soil-gas sampling were used with the following exceptions:

- Soil samples were screened in the field (OVA readings) using both a THVA and a PID in order to compare data from both devices.
- An extra soil sample (from 9 feet bgs in VMP-2 borehole) was submitted for laboratory analysis for TRPH and BTEX to evaluate the soils near the zone of floating product.
- Surface soil-gas samples during the air permeability test were collected and analyzed for TVH and BTEX to determine potential emissions of these analytes to the atmosphere resulting from air injection during the pilot test.
- The vapor monitoring point screen installed at 9 feet bgs in VMP-2 was positioned below the unsaturated zone (within the floating product layer and below the water table) to evaluate this zone in anticipation of a lower water table during dry seasons. This zone was within the unsaturated zone during previous site investigation work and soil samples from this interval from a nearby soil boring (SB-8) had significant concentrations of fuel hydrocarbons (see Part I).

3.0 PILOT TEST RESULTS

3.1 South Gas Station (SGS) Site

3.1.1. Initial Soil-Gas Chemistry

Prior to initiating any air extraction or injection, all VEWs and VMPs were purged until oxygen levels had stabilized, and then initial oxygen and carbon dioxide concentrations were sampled using portable gas analyzers as described in the protocol document (Hinchee et. al. 1992). Depleted oxygen levels and increased carbon dioxide levels were found in soil gas at all measurable VMP screened intervals, indicating significant soil contamination and natural biological activity at 5 to 15 feet bgs. Usable initial soil-gas samples could not be extracted from VMP1-14 and VMP2-6 due to saturated conditions most likely caused by recent heavy rains and/or the high water table. The initial soil-gas chemistry measured at the SGS site is summarized in Table 3.1. TRPH and BTEX concentrations for soil samples are also provided to demonstrate the relationship between oxygen levels and the contaminated soils.

The background VMP (VMP-3) had an oxygen level of 15 percent, a carbon dioxide level of 2.5 percent, and a TVH reading of 80 ppmv (measured using the THVA) at a depth of 6 feet. No observable fuel contamination in the soils was documented during boring operations. The oxygen and carbon dioxide levels at VMP3-6 indicate possible oxygen consumption unrelated to fuel contamination is occurring in the soils in the background well at the 6-foot depth. No background respiration test was performed to document this possibility, and therefore respiration rates reported in this study are not corrected for possible oxygen consumption unrelated to fuel contamination. However, a background respiration will be conducted at VMP-4 during the scheduled 6-month respiration test for Site 1 in order to perform any necessary corrections to O_2-utilization rates. No soil gas sample could be collected at the 14-foot depth due to apparent low permeable soil conditions.

3.1.2 Air Permeability

An air permeability (AP) test was conducted on 23 February 1993 according to protocol document procedures. Air was extracted from one of the vapor extraction wells (VEW-1) for approximately two hours at a rate of 24 scfm with an average vacuum at the well head of 133 inches of water (in. H_2O). The vacuum response at the VMP-2 screened interval at 6 feet bgs is shown in Figure 3.1. The calculated air permeability based on the dynamic response at VMP2-6 was 11 darcys, high for the clay-rich soil found at this depth. Although vacuum response was noted initially in all other VMPs, the vacuum dropped to near zero by the end of the test, probably due to saturation of soils at these other VMPs caused either by the recent rains and/or upwelling of the shallow water table.

Because of the rapid vacuum response of site soils to vapor extraction, calculation of air permeability was also performed using a steady-state method for comparison with the value calculated using the dynamic method. Based on a radius of vacuum influence of 25 feet, the calculated air permeability by the steady-state method was found to be 1.3 darcys. This value represents an average air permeability for all surrounding site soils. It is important to note that the 6-foot depth intervals at VMP-1 and VMP-2 were screened

Table 3.1
INITIAL CONDITIONS
South Gas Station (SGS) Site
Travis AFB, California

Well No.– depth	SOIL GAS O_2 (%)	SOIL GAS CO_2 (%)	SOIL GAS TVH–g (ppmv)	SOIL GAS TVH (ppmv)	SOIL TRPH (mg/kg)	SOIL Benzene (mg/kg)	SOIL Toluene (mg/kg)	SOIL Ethylbenzene (mg/kg)	SOIL Total Xylenes (mg/kg)
VEW1–(5 – 15)	1.0	7.5	140,000	>20,000	30	3.8	5.7	2.9	16
VMP1–6	2.5	9.0		>20,000					
VMP1–14					14	2.5	5.0	8.4	53
VMP2–6	2.0	7.2							
VMP2–14	4.0	12.0	150,000	>20,000	16	5.6	15	10	47
VEW2–(5–15)	1.0	9.0		>20,000					

LEGEND

(shaded) : Sample was not taken/analyzed.

TRPH : Total Recoverable Petroleum Hydrocarbons (EPA 418.1)

TVH–g : Total Volatile Hydrocarbons as gasoline (EPA TO–3)

TVH : Total Volatile Hydrocarbons (THVA field instrument)

ND : not detected

mg/kg : milligrams per kilogram

ppmv : parts per million by volume

NOTES

1. O_2/CO_2 measurements by field instrumentation.
2. Soil samples taken at a depth of 15 feet bgs.
3. Benzene, Toluene, Ethylbenzene, and Total xylenes by EPA Method 8020.

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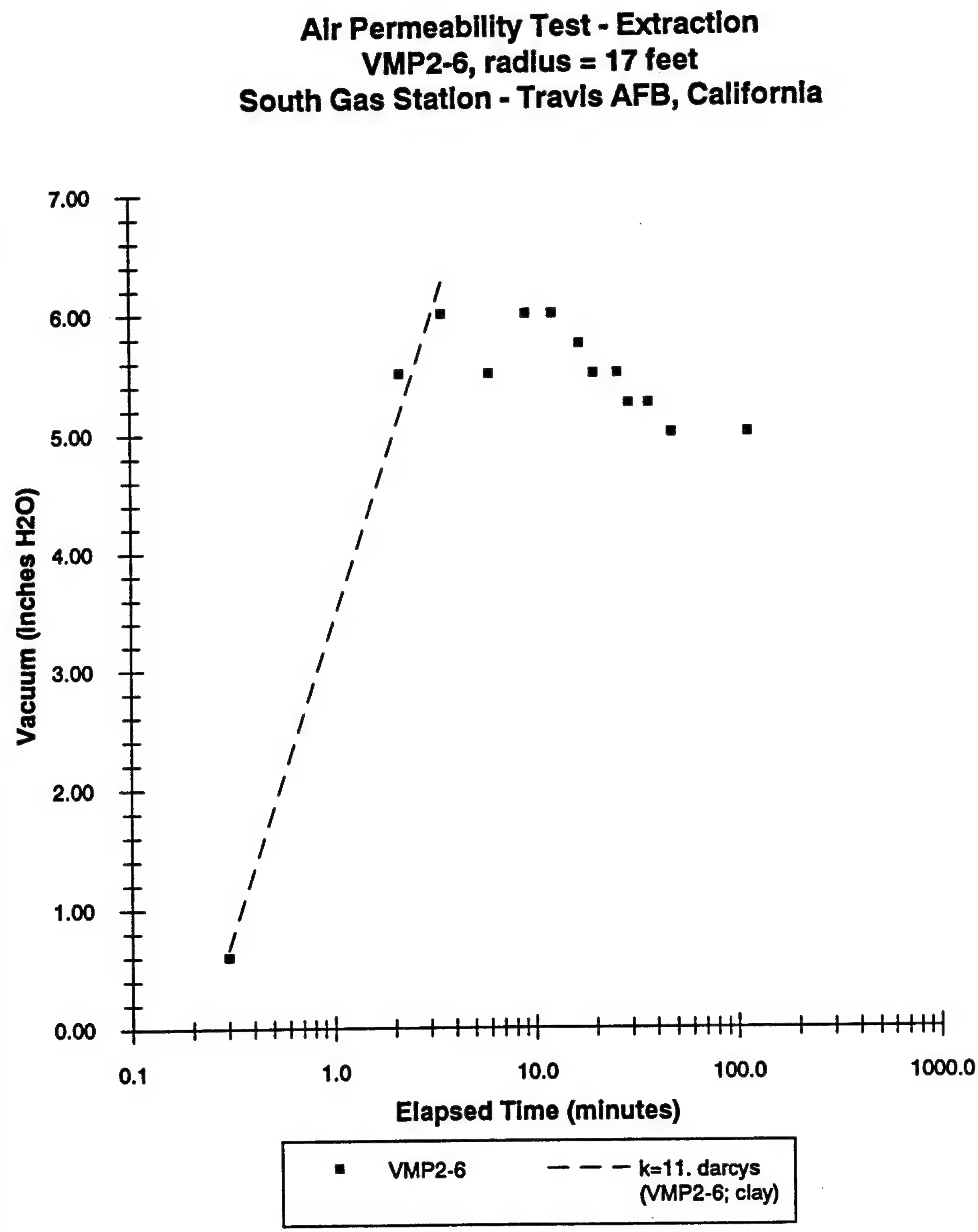

Air Permeability Test - Extraction
VMP2-6, radius = 17 feet
South Gas Station - Travis AFB, California
Vacuum (inches H2O)
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.1
1.0
10.0
100.0
1000.0
Elapsed Time (minutes)
VMP2-6
k=11. darcys
(VMP2-6; clay)

within clay, and the 14-foot depth intervals at both points were screened within sand; vacuum influence was seen initially in both soil types.

Two hours into the AP test using air extraction, it was noted that minor amounts of water and sediment were being drawn into the well and into the blower system piping. A second AP test was conducted using air injection at VEW-1 for twenty minutes at a rate of approximately 23 scfm with an average pressure at the well head of 208 in. H_2O. Pressure response and oxygen influence were measured at the 6-foot depth in both VMP-1 and VMP-2 during the short test. The pressure response at VMP2-6 is shown in Figure 3.2. Oxygen influence is discussed in Section 3.1.3. The calculated air permeability based on the dynamic response at VMP2-6 was 7 darcys, high for the clay-rich soil found at this depth, but consistent with the result found during the AP test by extraction. Insufficient pressure response data was collected at VMP1-6 to calculate air permeability.

The steady-state calculation method for air permeability is recommended for sites where changes in the pressure or vacuum take place quickly (less than ten minutes), where the venting screened interval is 10 feet or less, and/or where the groundwater table is high. All of these conditions were met at the SGS site; therefore, the more conservative value for air permeability of 1.3 darcys was used in assessing the suitability of the site for bioventing and in designing the extended pilot test system.

3.1.3 Oxygen Influence

The depth and radius of oxygen influence in the subsurface resulting from air extraction or injection during pilot testing is the primary design parameter for extended bioventing systems. The pilot test data determine the volume of soil that can be oxygenated at a given flow rate and vapor extraction well screen configuration.

Table 3.2 presents the change in soil-gas chemistry during the two AP tests. Changes in soil-gas oxygen levels occurred at VEW-1, VMP1-6, VMP2-6, and VEW-2, indicating successful oxygen transport even for relatively brief injection and extraction periods. At VMP1-6, the oxygen level appeared to decrease during air extraction, possibly due to displacement of oxygen-depleted soil-gas. Oxygen levels at the 14-foot depths could not be measured due to saturated conditions. However, as the water table drops and exposes the more permeable sand interval at that depth, oxygen influence would also be expected at this depth during extended bioventing.

Based on measurable vacuum and pressure response, which are indicators of long-term oxygen transport, and the change in oxygen levels during the short-term AP tests, it is anticipated that the radius of oxygen influence for a long-term bioventing system at this site will be at least 25 feet from both VEW-1 and VEW-2. The effective treatment radius for the extended pilot test will be better defined by monitoring the oxygen and contaminated soil-gas levels during the extended pilot test at the site.

3.1.4 *In Situ* Respiration Rates

An *in situ* respiration (ISR) test was conducted between 24 and 26 February 1993, according to protocol procedures. Air (20.8 percent oxygen) was injected at a rate of 1 scfm into 2 VMP screened intervals (VMP1-6 and VMP2-6) and VEW-2 for 16.5 hours

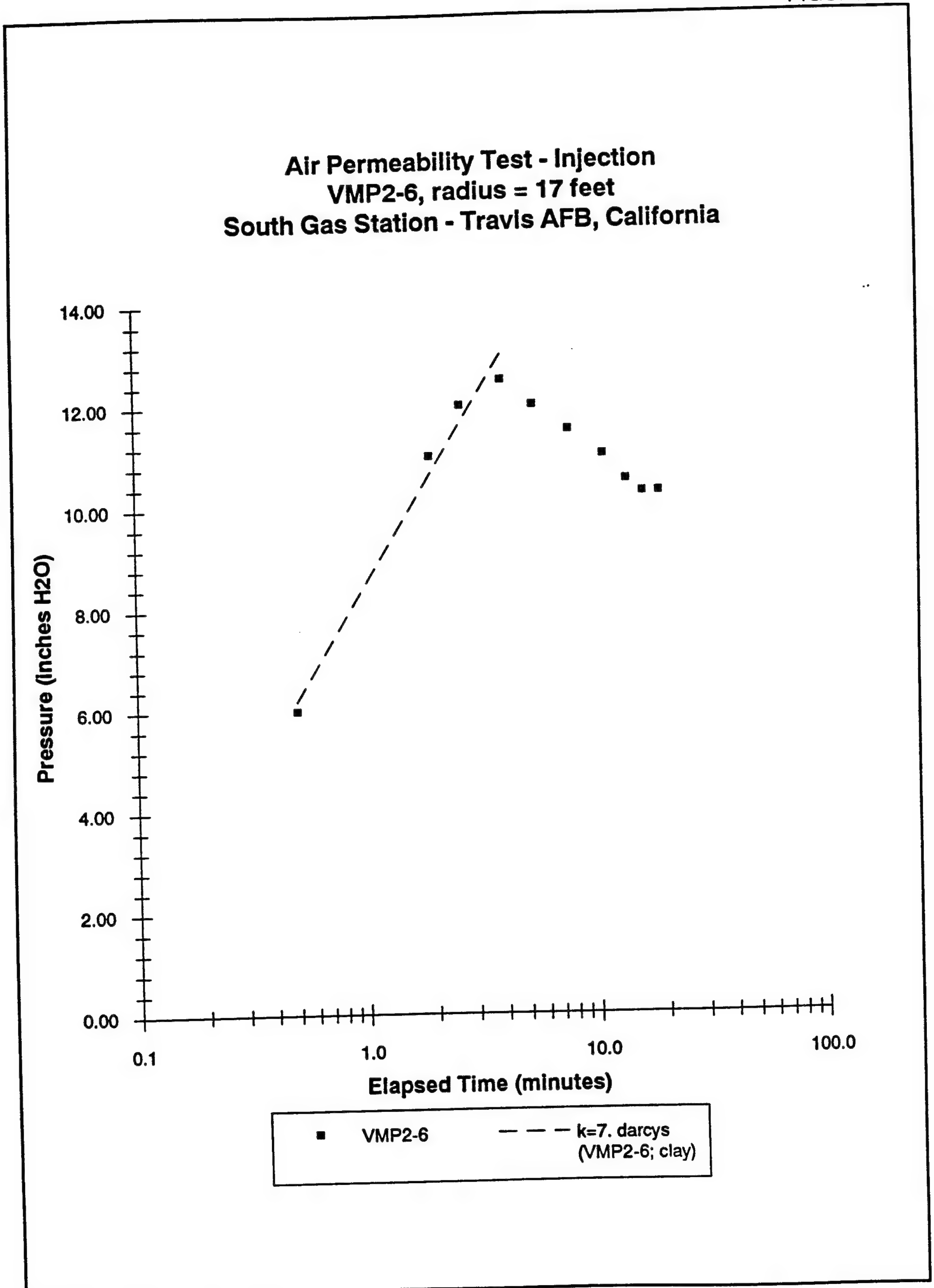
Air Permeability Test - Injection
VMP2-6, radius = 17 feet
South Gas Station - Travis AFB, California
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Pressure (inches H2O)
0.1
1.0
10.0
100.0
Elapsed Time (minutes)
VMP2-6
k=7. darcys
(VMP2-6; clay)

Table 3.2
INFLUENCE OF AIR EXTRACTION AND AIR INJECTION ON OXYGEN LEVELS
South Gas Station (SGS) Site
Travis AFB, California

Well No.– depth	Distance from VEW–1 (ft)	Inital O_2 (%)	Final O_2 (%)	Comments
VEW1–(5–15)	0	1.0	16.5	Extraction Test
VMP1–6	15	2.5	1.0	Extraction Test
VMP1–14	15			
VMP2–6	17	2.0	6.0	Injection Test
VMP2–14	17	4.0		Extraction Test
VEW2–(5–15)	45	1.0	8.5	Extraction Test

LEGEND

[shaded box] : Sample was not taken/analyzed.

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in order to oxygenate surrounding soils. After air injection was ceased, oxygen, carbon dioxide, and TVH levels were measured in soil gas for the following 22.5 hours. Oxygen utilization rates were then calculated and used to estimate biodegradation rates. Calculation sheets for these estimates are included in Appendix E. The results of the ISR test at this site are presented in Figures 3.3 to 3.5.

Results from the ISR test indicate that VMP1-6, VMP2-6, and VEW-2 had significant soil hydrocarbon contamination and active microorganism populations. The oxygen levels were below 5 percent during initial readings and, following aeration of surrounding soils to 21 percent oxygen, quickly dropped to lower levels. Oxygen loss occurred at high rates of 2.2, 2.3, and 2.9 percent per hour at VMP1-6, VMP2-6, and VEW-2, respectively. No helium was injected during the ISR test due to equipment problems.

Based on oxygen-utilization rates calculated at VMP1-6, VMP2-6, and VEW-2, an estimated 2,600 to 5,300 milligrams (mg) of fuel per kilogram (kg) of soil can be biodegraded each year at this site. The lower estimate reflects the difficulty of oxygenating very moist clays (found at VMP2-6), while the higher estimate applies to more permeable soils with lower moisture levels (found at VMP1-6 and VEW-2). These biodegradation rate estimates are based on calculated air-filled porosities, which averaged 0.045 liter of air per kg of soil, and a ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded (Appendix D). Methods of calculation followed the procedures in the protocol document.

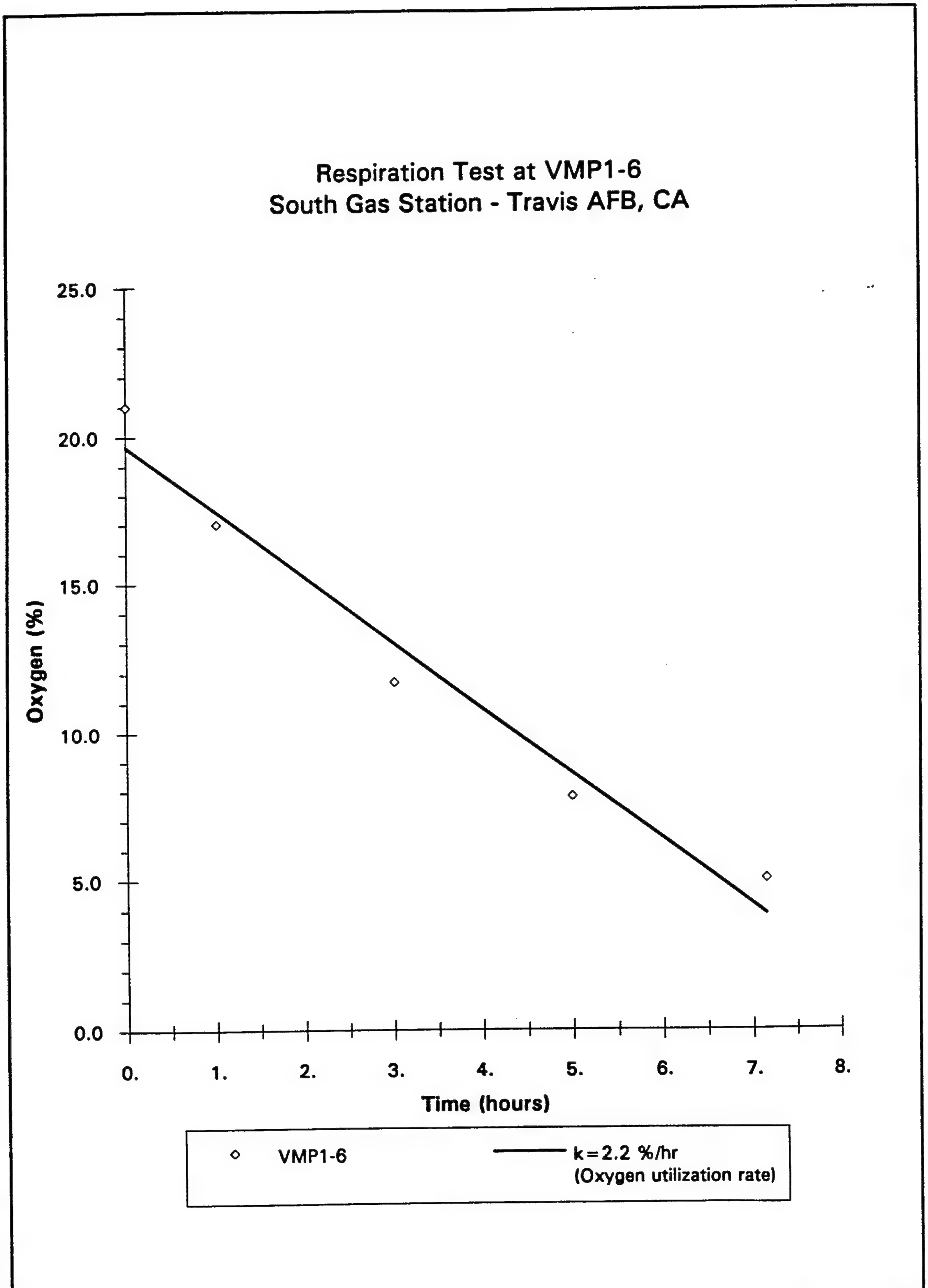
These biodegradation rates would be expected to increase during extended pilot testing as continued air extraction or injection increases air-filled porosity. Additional respiration testing at 6 months and one year following installation of an extended pilot test system, and soil sampling one year following installation, will better define the long-term biodegradation rates. Table 3.3 summarizes the data from the initial pilot test at the SGS site.

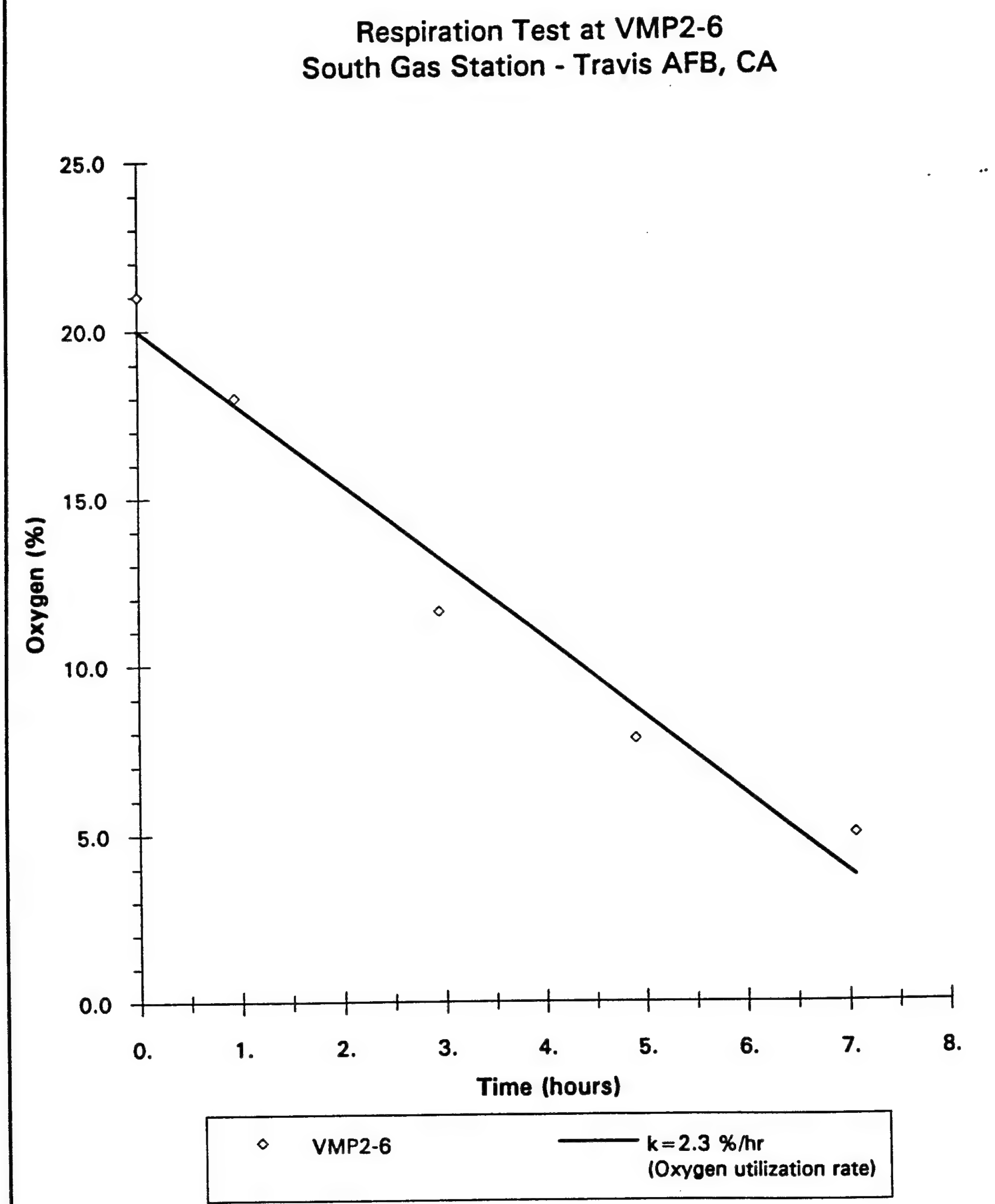
3.1.5 Potential Air Emissions

Air emission measurements were taken of the exhaust gas during the extraction AP test in order to evaluate the effectiveness of the off-gas treatment system. In addition, these measurements were used to estimate the emissions which could be expected from an extended pilot test system extracting air from the subsurface.

In order to determine the TVH-g and BTEX content of the soil-gas extracted from VEW-1 during the pilot test, two soil-gas samples were collected in evacuated, 1-liter Summa® cannisters. The samples were sent for laboratory analysis using EPA Method TO-3 to Air Toxics, Ltd. in Rancho Cordova, California. The first sample was collected prior to the start of the AP test and the second sample was collected at the end of the 2-hour AP test. Results from these samples were shown in Table 2.1 as soil-gas samples VEW1 and VEW1(PP), respectively.

Based on the laboratory analysis results, it appears that extracted volatile hydrocarbon concentrations (TVH-g, benzene, and toluene) decreased significantly during the short duration of the AP test and should continue to do so during an extended pilot test.


Respiration Test at VMP1-6
South Gas Station - Travis AFB, CA
25.0
20.0
15.0
10.0
5.0
0.0
Oxygen (%)
0.
1.
2.
3.
4.
5.
6.
7.
8.
Time (hours)
VMP1-6
k=2.2 %/hr
(Oxygen utilization rate)


Respiration Test at VMP2-6
South Gas Station - Travis AFB, CA
25.0
20.0
15.0
10.0
5.0
0.0
Oxygen (%)
0.
1.
2.
3.
4.
5.
6.
7.
8.
Time (hours)
VMP2-6
k=2.3 %/hr
(Oxygen utilization rate)

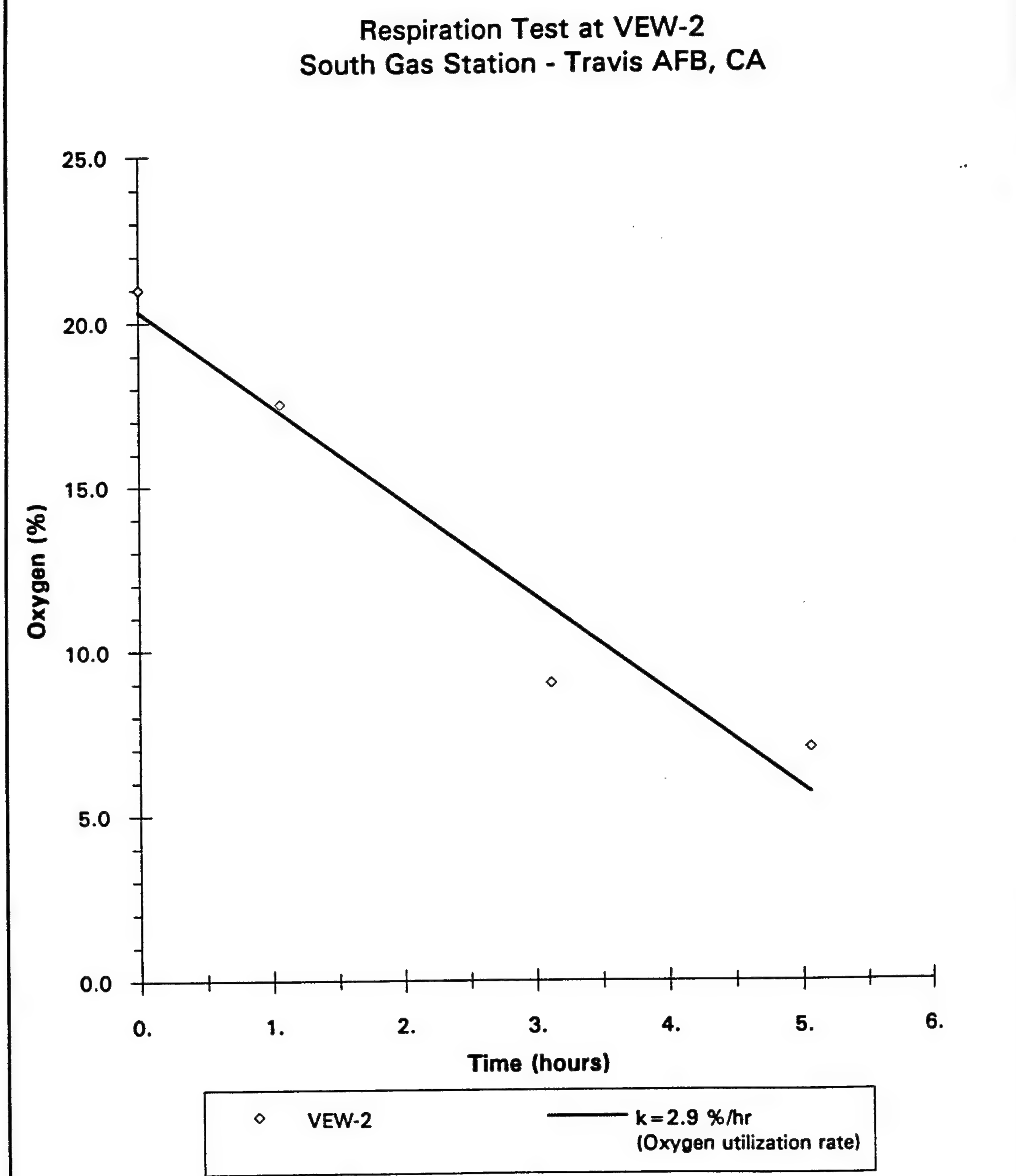

Respiration Test at VEW-2
South Gas Station - Travis AFB, CA
25.0
20.0
15.0
10.0
5.0
0.0
Oxygen (%)
0.
1.
2.
3.
4.
5.
6.
Time (hours)
VEW-2
k=2.9 %/hr
(Oxygen utilization rate)

Table 3.3
PILOT TEST DATA SUMMARY
South Gas Station (SGS) Site
Travis AFB, California

	Soil and Soil Gas Data			Air Permeability Test				*In Situ* Respiration Test					Calculated Biodegradation Rate
	Soil Type	Laboratory Analytical Results		Initial Soil Gas		Final Soil Gas	Air Perm.	Initial Soil Gas		Final Soil Gas		O_2 Util. Rate	
WELL No.–DEPTH		TRPH (mg/kg)	TVH–g (ppmv)	O_2 (%)	CO_2 (%)	O_2 (%)	k (darcy)	O_2 (%)	He (%)	O_2 (%)	He (%)	k_o (%/hr)	K_b (mg fuel/kg soil per year)
VEW1–(5 – 15)	SAND	30	140,000	1.0	7.5	16.5	1.3 (note 3)						
VMP1–6	clayey SILT			2.5	9.0	1.0	1.3 (note 3)	21		5.0		2.2	3,400
VMP1–14	SAND	14					1.3 (note 3)						
VMP2–6	CLAY			2.0	7.2	6.0	1.3 (note 3)	21		5.0		2.3	2,600
VMP2–14	silty CLAY	16	150,000	4.0	12.0	4.0	1.3 (note 3)						
VEW2–(5–15)	silty SAND			1.0	9.0	8.5	1.3 (note 3)	21		7.0		2.9	5,300

LEGEND

(shaded) : Sample was not taken/analyzed.

TRPH : Total Recoverable Petroleum Hydrocarbons (EPA 418.1)

TVH–g : Total Volatile Hydrocarbons as gasoline (EPA TO–3)

ND : not detected

mg/kg : milligrams per kilogram

ppmv : parts per million by volume

NOTES

1. VEW1 soil sample collected from 15 ft bgs.
2. Air Permeability Test conducted for 2 hrs at air extraction rate of 23 scfm.
3. Air permeability, k, calculated based on radius of influence of 25 feet and respresents average value for site soils.
4. *In Situ* Respiration Test: air injection at selected VMPs for 16.5 hrs at 1.1 scfm; O_2/CO_2/TVH measurements taken for 22.5 hrs following injection.
5. Helium not monitored during ISR test due to equipment trouble.

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The proposed extended pilot test system design for the SGS site is described in detail in Section 4.

In addition to the laboratory samples, field OVA measurements were taken from soil-gas collected at the entry and exit points of the GAC treatment system at the start of the AP test and at the end of the AP test. These results were used to verify the effectiveness of the GAC treatment system to treat the off-gas before venting to the atmosphere. At the start of the AP test, TVH was measured at >20,000 ppmv and 48 ppmv, at the entry and exit points respectively, resulting in a removal efficiency of at least 99.8 percent. At the end of the AP test, TVH measurements were 17,200 ppmv and 100 ppmv at the entry and exit points, respectively, resulting in a removal efficiency of 99.4 percent.

3.1.6 Recommendations

Initial bioventing tests at the SGS site indicate that oxygen has been depleted in the contaminated soils, and that air injection or extraction are effective methods of increasing aerobic biodegradation of fuel. The Air Force Center for Environmental Excellence (AFCEE) has recommended that air injection be implemented at this site to determine the long-term radius of oxygen influence and the effect of time, available nutrients, and changing soil temperatures on fuel biodegradation rates. Due to the high levels of volatile components in soil gas at the SGS site, air injection will be preceded by one to two months of soil vapor extraction (SVE) to significantly reduce soil vapor hydrocarbon levels. The extended pilot test system design for the SGS site, including off-gas treatment, is discussed fully in Section 4.

A respiration test is recommended at the background VMP (VMP-4) for this site to document the possibility of oxygen consumption unrelated to fuel contamination in the soils to modify the O_2-utilization estimates, if necessary.

3.2 Fuel Storage Area G (Site 1)

3.2.1 Initial Soil-Gas Chemistry

Prior to initiating air injection, the VW and VMPs were purged until oxygen levels had stabilized, and then initial oxygen and carbon dioxide concentrations were sampled using portable gas analyzers as described in the protocol document (Hinchee et. al. 1992). Depleted oxygen levels and increased carbon dioxide levels were found in soil gas at all measurable VMP screened intervals, indicating significant soil contamination and natural biological activity. Usable initial soil-gas samples could not be extracted from VMP2-9 because it was below the water table, and also could not be collected from VMP3-3.5 due to apparent flooding of the screened interval. The initial soil-gas chemistry measured at Site 1 is summarized in Table 3.4. TRPH and BTEX concentrations for soil samples are also provided to demonstrate the relationship between oxygen levels and the contaminated soils.

The background VMP (VMP-4) had oxygen levels of 21 percent and 14.5 percent and carbon dioxide levels of 0.25 and 0.7 percent at depths of 3.5 feet and 6.5 feet, respectively. Total volatile hydrocarbons (TVH) in soil-gas at VMP-4 was also measured using the THVA. TVH levels were 0 ppmv and 320 ppmv at 3.5 feet and 6.5 feet,

Table 3.4
INITIAL CONDITIONS
Fuel Storage Area G (Site 1)
Travis AFB, California

Well No.– depth	SOIL GAS O_2 (%)	CO_2 (%)	TVH–jf (ppmv)	TVH (ppmv)	SOIL TRPH (mg/kg)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Total Xylenes (mg/kg)
VW1–(5 – 12)	0.8	14.0	110,000	>10,000	ND	0.022	0.030	0.012	0.040
VMP1–3.5	3.5	8.0		>10,000					
VMP1–6.5	1.0	14.5	120,000	>10,000	ND	0.026	0.027	0.013	0.042
VMP2–5	1.5	15.5		>10,000	12	0.38	2.0	1.5	5.8
VMP2–9					230	ND	ND	35	45
VMP3–3.5									
VMP3–6.5	2.5	15.0	110,000	>10,000					

LEGEND

(shaded) : Sample was not taken/analyzed.
TRPH : Total Recoverable Petroleum Hydrocarbons (EPA 418.1)
TVH–jf : Total Volatile Hydrocarbons as jet fuel (EPA TO–3)
TVH : Total Volatile Hydrocarbons (THVA field instrument)
ND : not detected
mg/kg : milligrams per kilogram
ppmv : parts per million by volume

NOTES

1. O_2/CO_2 measurements by field instrumentation.
2. Soil samples taken at a depth of 6 feet bgs, except VMP2–9, which was taken at 9 feet bgs.
3. Benzene, Toluene, Ethylbenzene, and Total xylenes by EPA Method 8020.

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respectively. No observable fuel contamination in the soils was documented during boring operations. The TVH level indicates the possibility of soil-gas contamination at the 6.5-foot depth, which could be the result of fuel volatilization from groundwater immediately below this depth (groundwater contamination has not been documented at this location). The O_2 and CO_2 levels at VMP4-6.5 indicate either slight soil-gas contamination, or possibly the occurrence of oxygen consumption unrelated to fuel contamination in the soils at this depth. However, the soil-gas readings at 3.5 feet indicate that native soils probably do not contain inorganic or natural carbon sources which would contribute to oxygen uptake. No background respiration test was performed to document the possibility of oxygen consumption unrelated to fuel contamination in the soils, and therefore respiration rates reported in this study are not corrected for this possibility. However, a background respiration test will be conducted during the scheduled 6-month respiration test in order to perform any necessory corrections to O_2-utilization rates.

3.2.2 Air Permeability

An air permeability (AP) test was conducted on 8 June 1993 according to protocol document procedures. Air was injected at VW-1 for approximately two hours at a rate of 3.5 scfm with an average pressure at the well head of 125 in. H_2O. The pressure responses at the VMPs are shown in Figure 3.6 through Figure 3.8.

Due to the slow response and relatively long time to achieve steady-state, the dynamic response method was used to calculate air permeability values, as detailed in the protocol document. Calculated air permeabilities were 1.4 darcys, 1.3 darcys, 1.5 darcys, and 1.8 darcys for VMP1-3.5, VMP1-6.5, VMP2-5, and VMP3-6.5, respectively. These values are in good agreement with each other, although they may seem high for a clayey silt. However, laboratory grain size analysis indicated a significant sand fraction (see Table 2.2), which could explain the higher permeabilities encountered during the test.

Although pressure response was noted initially in VMP2-9, the pressure rapidly dropped to near zero, probably due to saturation of soil near the water table. Response at VMP3-3.5 could not be measured because of apparent flooding in the screened interval.

3.2.3 Oxygen Influence

The depth and radius of oxygen influence in the subsurface resulting from air injection into the VW during pilot testing is the primary design parameter for extended bioventing systems. The pilot test data determine the volume of soil that can be oxygenated at a given flow rate and vent well screen configuration.

Table 3.5 presents the change in soil-gas chemistry during the AP test. Changes in soil-gas oxygen levels were measured at VMP1-6.5, VMP2-5, and VMP3-6.5, indicating successful oxygen transport in all VMPs and to a distance of at least 20 feet during the relatively brief injection period. Oxygen levels at VMP-2 at the 9-foot depth could not be measured due to saturated conditions. However, as the water table drops and exposes the more permeable sand interval at that depth, oxygen influence would also be expected at this depth during extended bioventing.

FIGURE 3.6

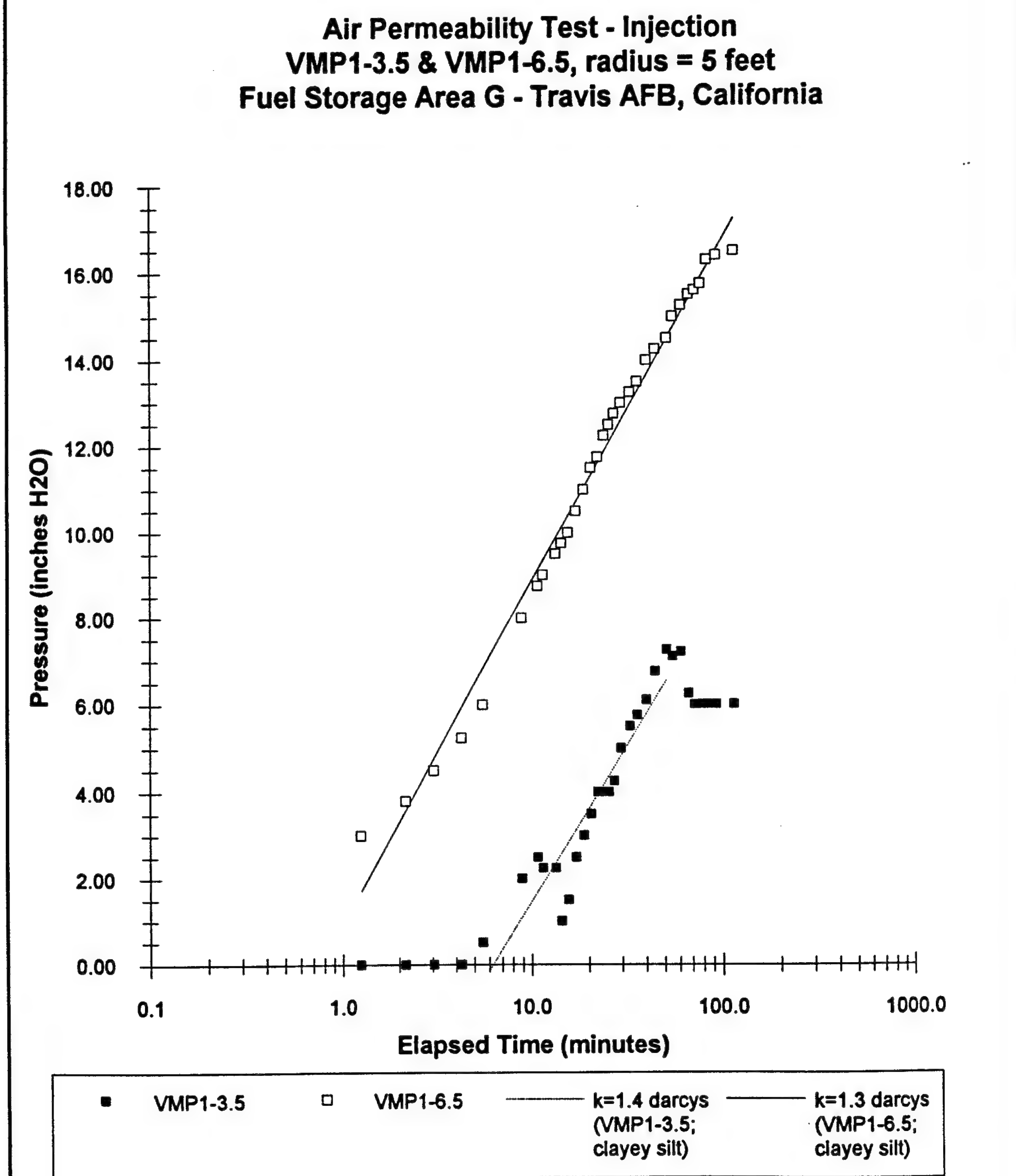

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FIGURE 3.7

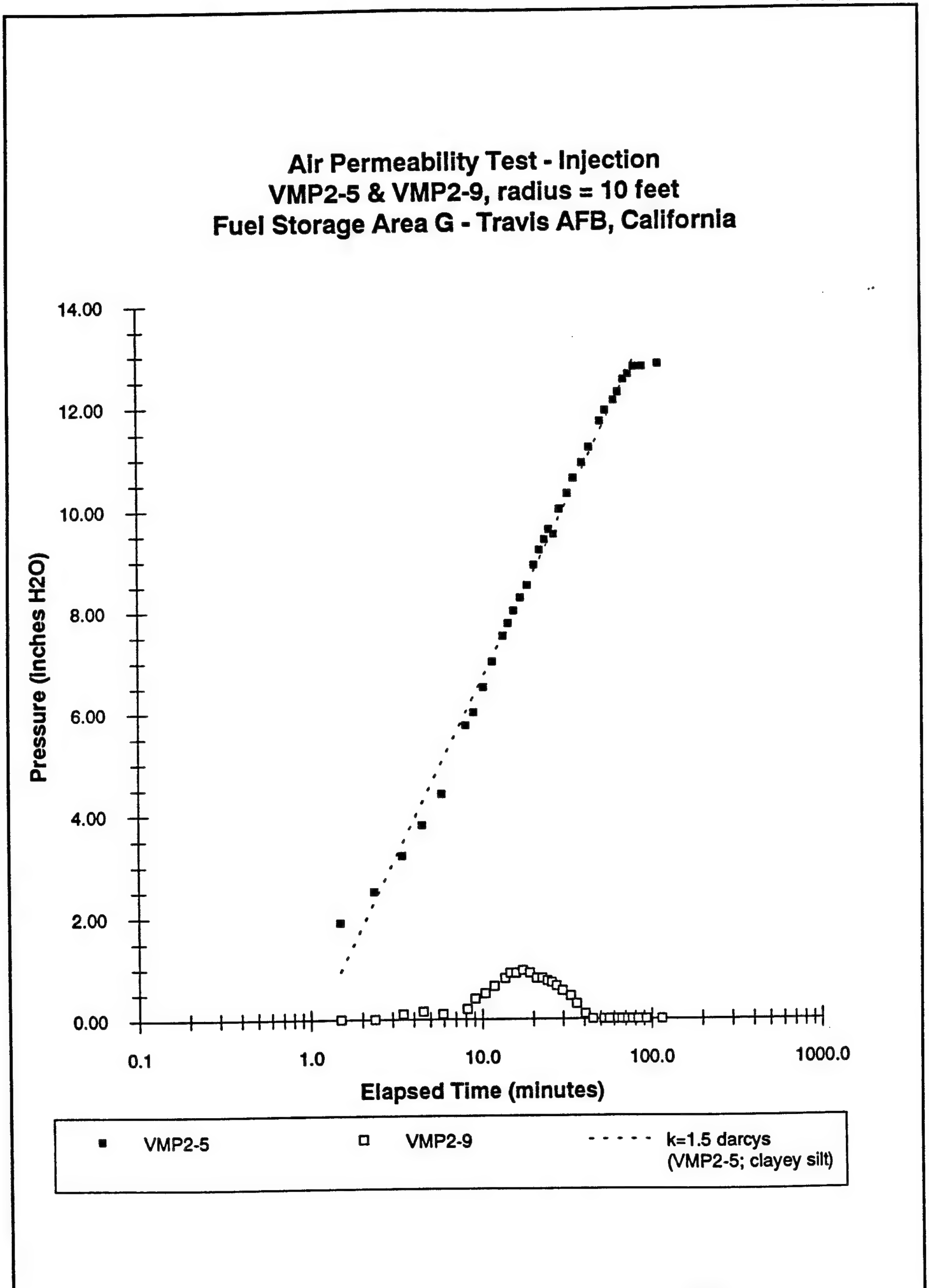
Air Permeability Test - Injection
VMP2-5 & VMP2-9, radius = 10 feet
Fuel Storage Area G - Travis AFB, California
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Pressure (inches H2O)
0.1
1.0
10.0
100.0
1000.0
Elapsed Time (minutes)
VMP2-5
VMP2-9
k=1.5 darcys
(VMP2-5; clayey silt)

FIGURE 3.8

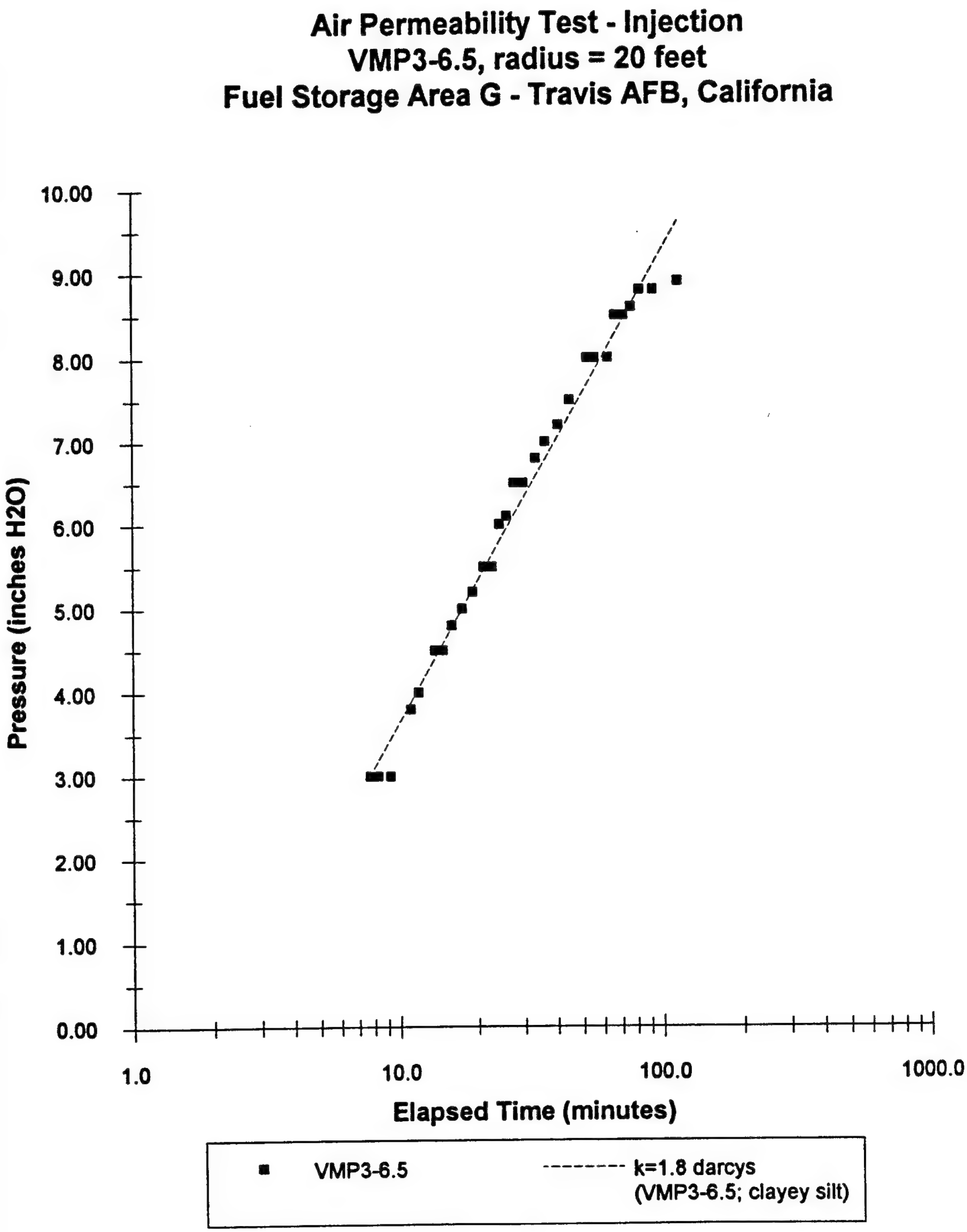
Air Permeability Test - Injection
VMP3-6.5, radius = 20 feet
Fuel Storage Area G - Travis AFB, California
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Pressure (inches H2O)
1.0
10.0
100.0
1000.0
Elapsed Time (minutes)
VMP3-6.5
k=1.8 darcys
(VMP3-6.5; clayey silt)

Table 3.5
INFLUENCE OF AIR INJECTION ON OXYGEN LEVELS
Fuel Storage Area G (Site 1)
Travis AFB, California

Well No.– depth	Distance from VEW–1 (ft)	Inital O_2 (%)	Final O_2 (%)
VW1–(5–12)	0	0.8	
VMP1–3.5	5	3.5	
VMP1–6.5	5	1.0	18.0
VMP2–5	10	1.5	8.5
VMP2–9	10		
VMP3–3.5	20		
VMP3–6.5	20	2.5	6.0

LEGEND

: Sample was not taken/analyzed.

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Based on measurable pressure response, which is an indicator of long-term oxygen transport, and the change in oxygen levels during the short-term AP test, it is anticipated that the radius of oxygen influence for a long-term bioventing system at this site will be at least 25 feet from VW-1. The effective treatment radius for the extended pilot test will be better defined by monitoring the oxygen and contaminated soil-gas levels during the extended pilot test at the site.

3.2.4 *In Situ* Respiration Rates

An *in situ* respiration (ISR) test was conducted between 9 and 10 June 1993 according to protocol procedures. Air (20.8 percent oxygen) was injected at a rate of 1 scfm into 4 VMP screened intervals (VMP1-3.5, VMP1-6.5, VMP2-5, and VMP3-6.5) for 23.5 hours in order to oxygenate surrounding soils. After air injection was ceased, oxygen, carbon dioxide, and TVH levels were measured in soil gas for the following 7 hours. Oxygen utilization rates were then calculated and used to estimate biodegradation rates. Calculation sheets for these estimates are included in Appendix D. The results of the ISR test at this site are presented in Figures 3.9 to 3.13.

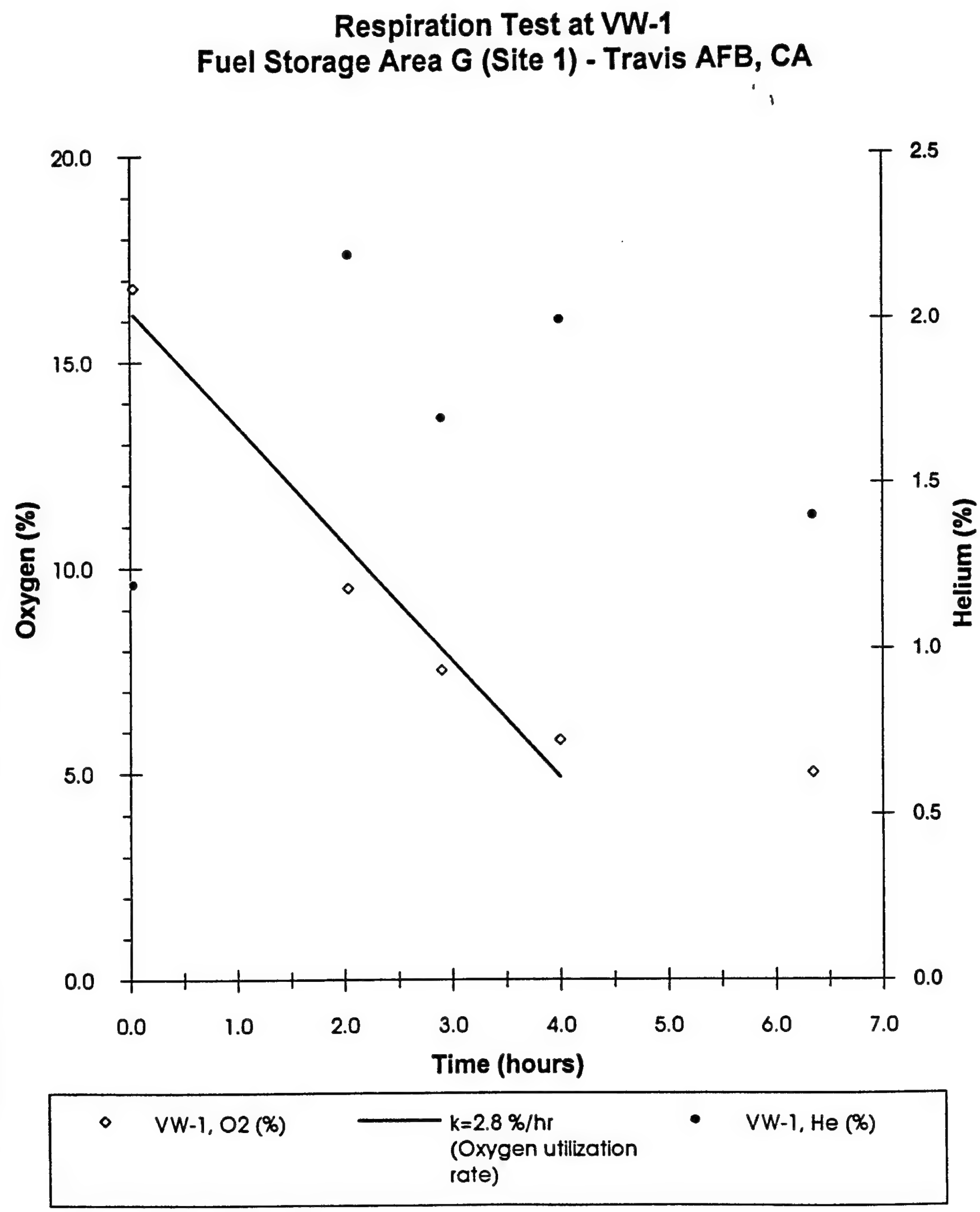
Results from the ISR test indicate that the VW and VMP1-3.5, VMP1-6.5, VMP2-5, and VMP3-6.5 had significant soil hydrocarbon contamination and active microorganism populations. All oxygen levels were below 4 percent during initial readings and, following aeration of surrounding soils to approximately 18 percent oxygen, quickly dropped to lower levels. Oxygen loss occurred at high rates of 2.8, 3.1, 4.3, 4.0, and 3.9 percent per hour at VW-1, VMP1-3.5, VMP1-6.5, VMP2-5, and VMP3-6.5, respectively.

The air injected into the four VMPs during the ISR test was a 2-percent helium mixture in air. The helium is used as a tracer gas to evaluate the effectiveness of the bentonite seals in the VW and VMPs. No appreciable loss of helium occurred between the end of air injection and the time that low oxygen levels were measured after seven hours. Therefore, most of the oxygen loss observed during the ISR test was a result of bacterial respiration and not faulty well construction. Helium was also measured at VW-1, although the air-helium mixture was not injected at that point. Detection of helium at VW-1 provides some evidence that significant volumes of soil were aerated by the 1 scfm pumps.

Based on oxygen-utilization rates calculated at VW-1 and the VMPs, an estimated 3,700 to 7,100 milligrams (mg) of fuel per kilogram (kg) of soil can be biodegraded each year at this site. The lower estimate reflects the slightly lower respiration rates found at VW-1, while the higher estimate reflects the higher respiration rate and larger air-filled porosities found at VMP2-5. These biodegradation rate estimates are based on calculated air-filled porosities, which averaged 0.20 liter of air per kg of soil, and a ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded (Appendix D). Methods of calculation followed the procedures in the protocol document.

These biodegradation rates are extremely high for soils with low TRPH and BTEX concentrations compared to rates measured at several other sites across the U.S. with similar soil types and fuel hydrocarbon concentrations. It is likely that these high biodegradation rates are due to the existence of the free product layer on top of the

FIGURE 3.9



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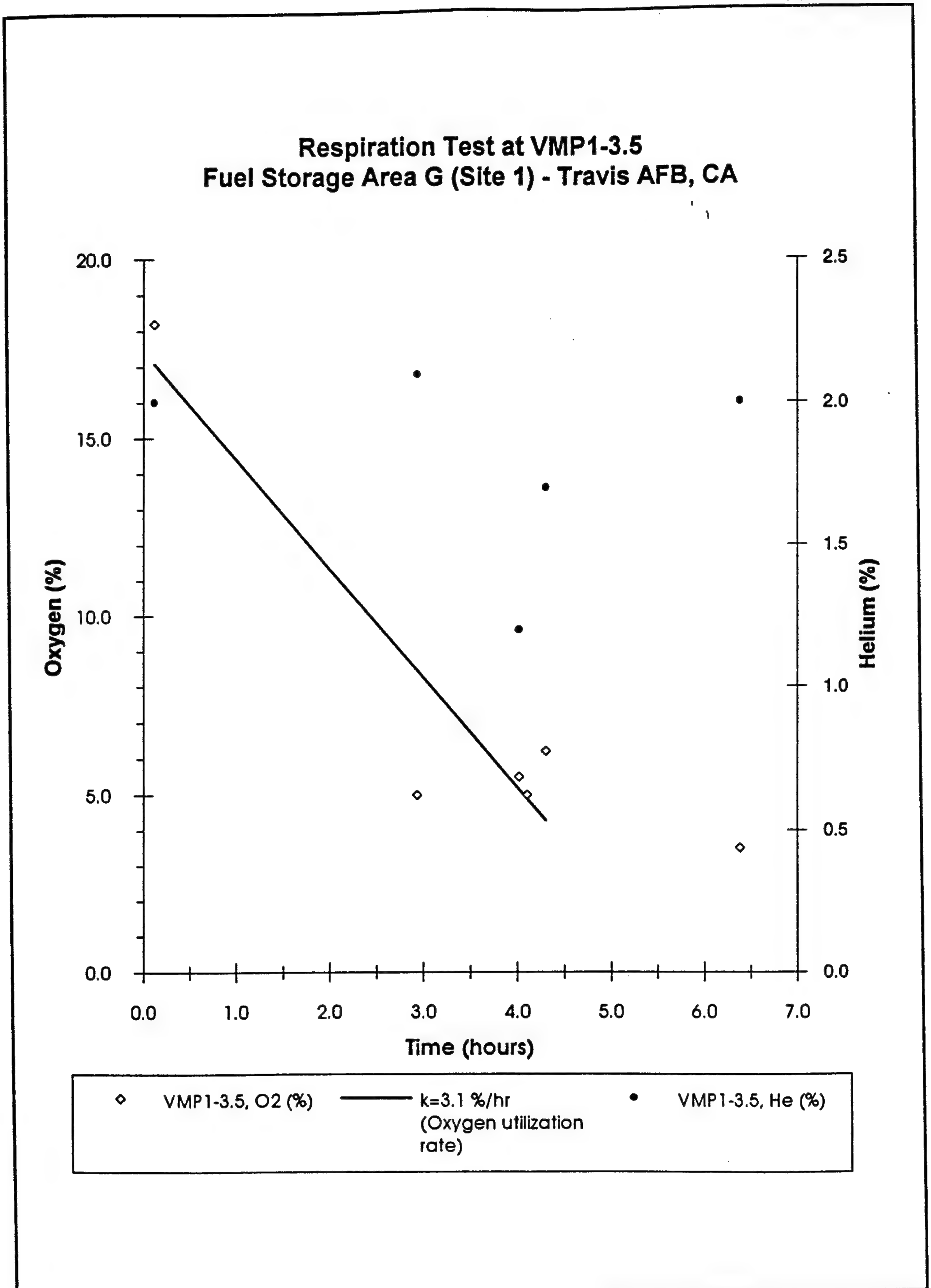

Respiration Test at VMP1-3.5
Fuel Storage Area G (Site 1) - Travis AFB, CA
20.0
15.0
10.0
5.0
0.0
Oxygen (%)
2.5
2.0
1.5
1.0
0.5
0.0
Helium (%)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Time (hours)
VMP1-3.5, O2 (%)
k=3.1 %/hr (Oxygen utilization rate)
VMP1-3.5, He (%)

FIGURE 3.11

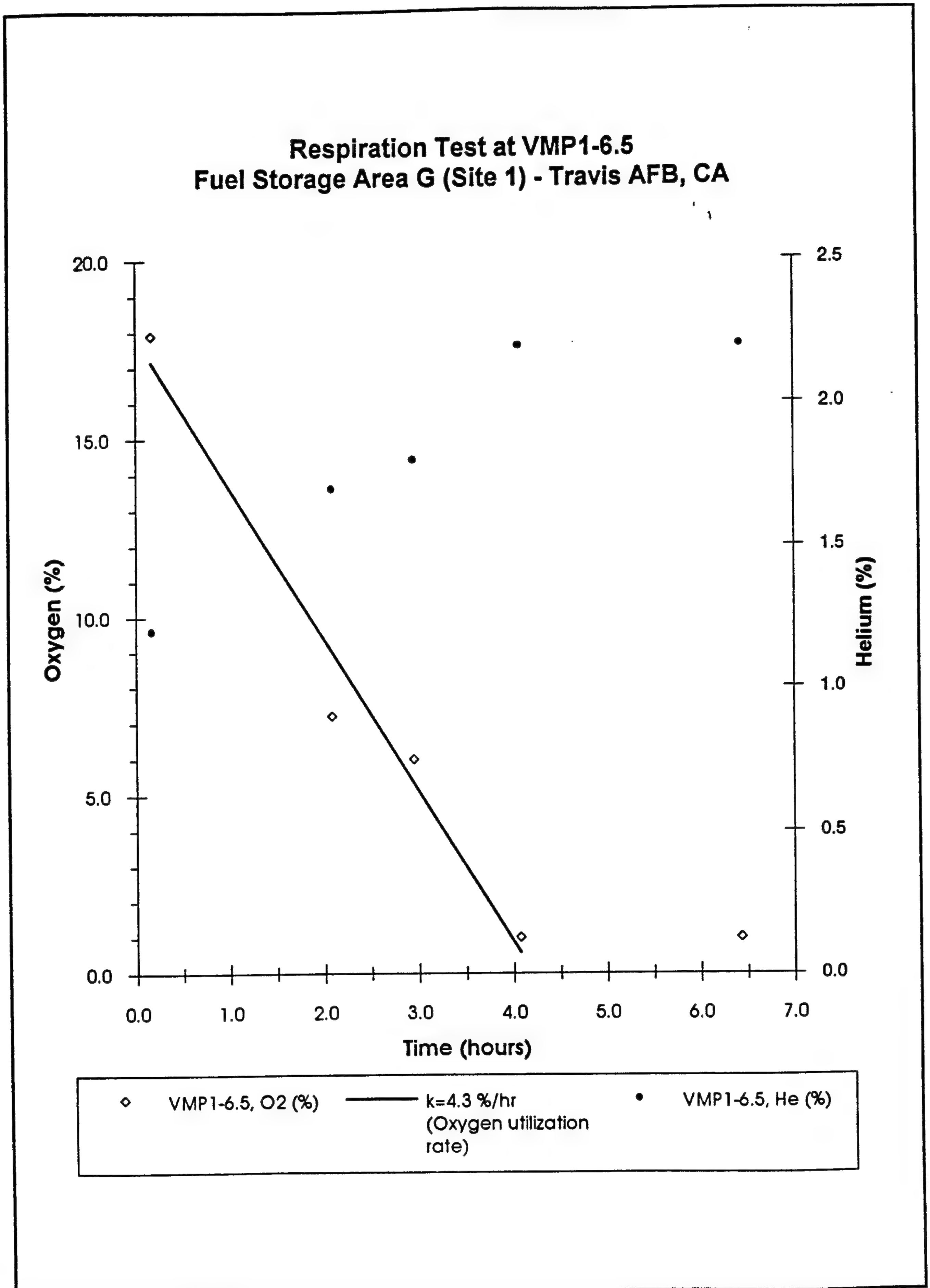

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FIGURE 3.12

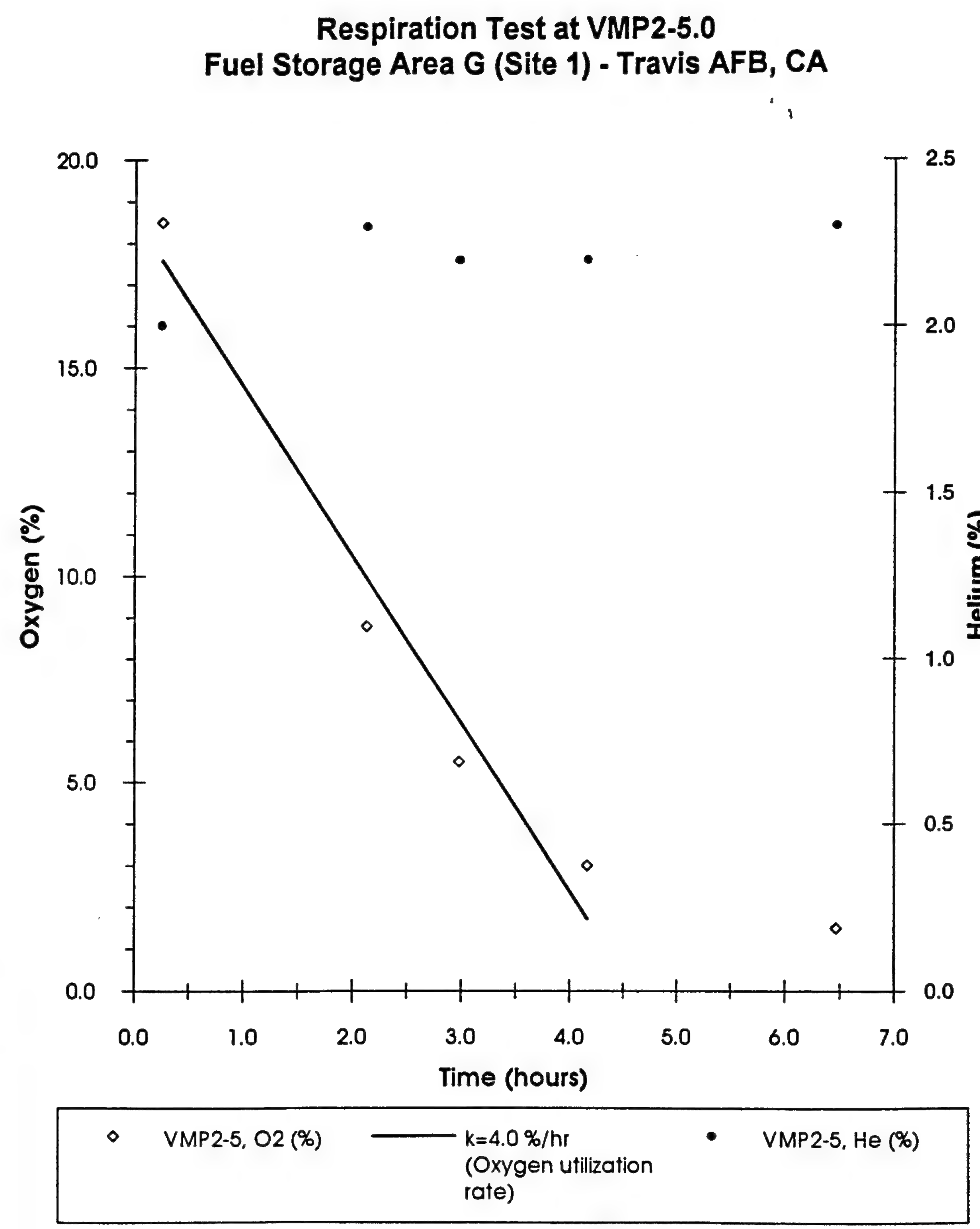

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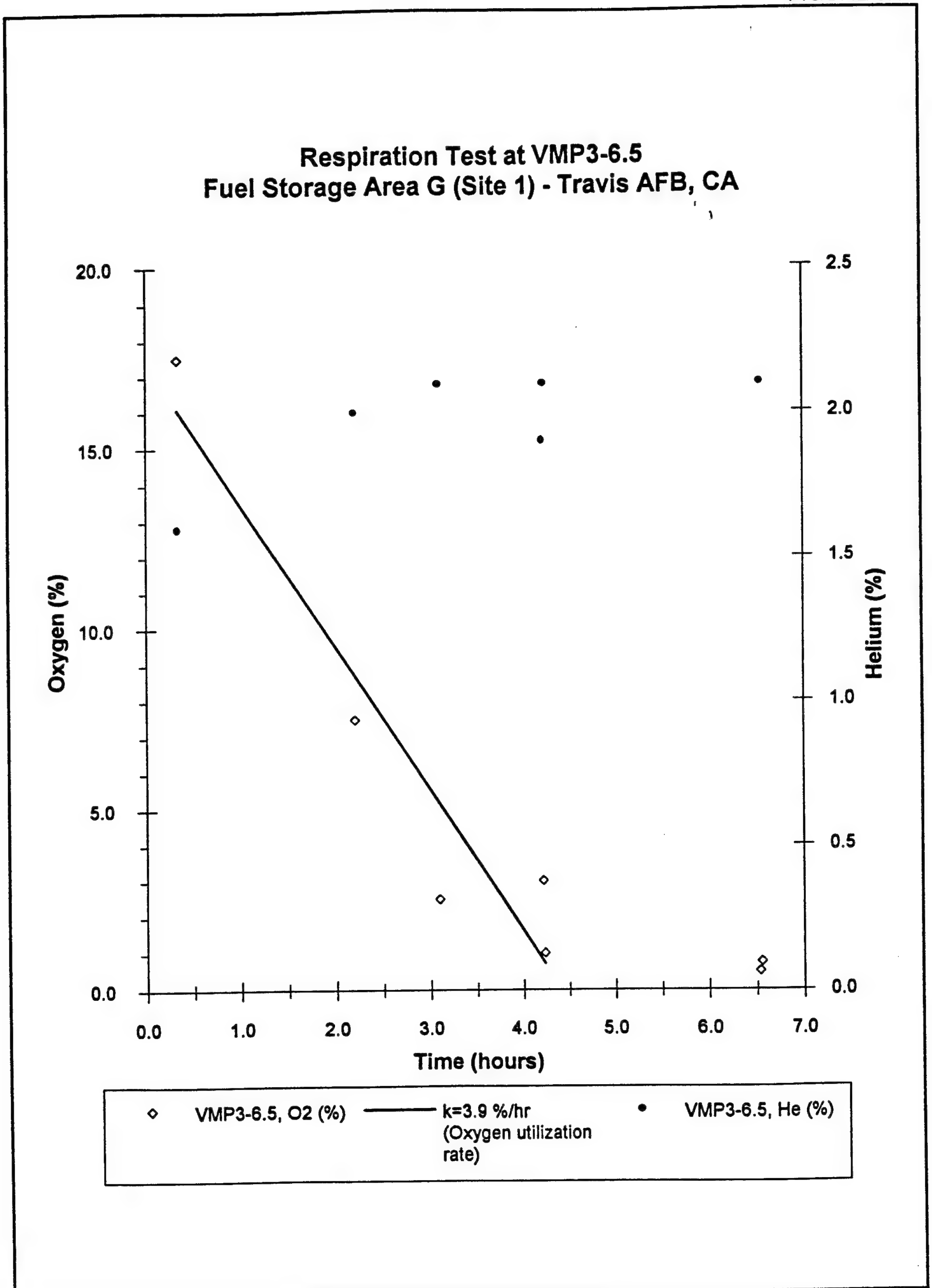
FIGURE 3.13



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groundwater just below the site. The source of hydrocarbon contamination and subsequent biologic activity in the vadose zone is probably from volatile hydrocarbons in the soil gas rather than contamination residuals sorbed onto the soil, which are measured by the laboratory analysis. In addition, in previous studies (Schwille 1976) recently summarized (Deyo et al. 1993), it has been observed that aerobic biodegradation of petroleum hydrocarbons dissolved in the groundwater decreases dissolved oxygen content. This change in dissolved oxygen would be expected to result in changes in soil-gas composition through gas exchange, with the water acting as a sink for soil-gas oxygen.

These biodegradation rates would be expected to increase during extended pilot testing as continued air injection increases air-filled porosity. Additional respiration testing at 6 months and one year following the installation of the extended pilot test system, and soil sampling one year following installation, will better define the long-term biodegradation rates. Table 3.6 summarizes the data from the initial pilot test at Site 1.

3.2.5 Potential Air Emissions

Air emission measurements were taken at Site 1 before and during air injection in order to evaluate the potential for discharge of hydrocarbons to the atmosphere resulting from subsurface air injection. The results indicate that no increase in TVH or BTEX levels above those found currently at the site occurred due to air injection.

TVH was measured at the ground surface before and during air injection at nine locations. The measurement locations were arranged around the injection well (VW-1) radiating outward in three arms of three points each, spaced roughly 120 degrees apart. The points in each arm were spaced at 6.5, 13, and 19 feet from the injection well. Hydrocarbon emissions were measured with both field instrumentation and laboratory analysis. TVH measurements were taken by placing a simple flux chamber on the ground surface and then withdrawing gas samples at a rate of 1 liter per minute into the THVA. The air in the flux chamber was sampled continuously for a period of 5 minutes at each location, and the highest reading was recorded in the field notebook. Results from these field measurements are shown in Table 3.7.

In order to determine the TVH-jf and BTEX content of the soil-gas emissions, two soil-gas samples were collected for laboratory analysis from a monitoring location 6.5 feet from the injection well. The first sample (BKT-1) was collected before air injection was begun and the second sample (BKT-2) was collected after 2 hours of air injection. The samples were collected in evacuated, 1-liter Summa® cannisters. The samples were sent for laboratory analysis using EPA Method TO-3 to Air Toxics, Ltd. in Rancho Cordova, California. Results from these samples were shown in Table 2.2.

Based on the laboratory analysis and field results, it appears that no significant levels of TVH or BTEX emissions resulted from air injection. BTEX levels from the air sample taken after injection were non-detect. TVH emissions appear to be confined to within a 13-foot radius of VW-1. Total hydrocarbon emissions are conservatively estimated at only 62 grams per day (about 0.1 pounds per day), assuming all air flow escapes to the

Table 3.6
PILOT TEST DATA SUMMARY
Fuel Storage Area G (Site 1)
Travis AFB, California

	Soil and Soil Gas Data			Air Permeability Test				*In Situ* Respiration Test					Calculated Biodegradation Rate
	Soil Type	Laboratory Analytical Results		Initial Soil Gas		Final Soil Gas	Air Perm.	Initial Soil Gas		Final Soil Gas		O_2 Util. Rate	
WELL No.–DEPTH		TRPH (mg/kg)	TVH–jf (ppmv)	O_2 (%)	CO_2 (%)	O_2 (%)	k (darcy)	O_2 (%)	He (%)	O_2 (%)	He (%)	k_o (%/hr)	K_b (mg fuel/kg soil per year)
VW1–(5 – 12)	clayey SILT	ND	110,000	0.8	14.0			16.8	1.2	5.0	1.4	2.8	4,500
VMP1–3.5	clayey SILT			3.5	8.0		1.4	18.2	2.0	3.5	2.0	3.1	3,900
VMP1–6.5	clayey SILT	ND	120,000	1.0	14.5	18.0	1.3	18.0	1.2	1.0	2.2	4.3	4,900
VMP2–5.0	clayey SILT	12		1.5	15.5	8.5	1.5	18.5	2.0	1.5	2.3	4.0	7,000
VMP2–9.0	clayey SAND	230											
VMP3–3.5	clayey SILT												
VMP3–6.5	clayey SILT		110,000	2.5	15.0	6.0	1.8	17.5	1.6	0.75	2.1	3.9	3,700

LEGEND

: Sample was not taken/analyzed.

TRPH : Total Recoverable Petroleum Hydrocarbons (EPA 418.1)

TVH–jf : Total Volatile Hydrocarbons as jet fuel (EPA TO–3)

ND : not detected

mg/kg : milligrams per kilogram

ppmv : parts per million by volume

NOTES

1. VW1 soil sample collected from 6 ft. bgs.
2. Air Permeability Test conducted for 2 hrs at air injection rate of 3.5 scfm.
3. *In Situ* Respiration Test: air injection at selected VMPs for 23.5 hrs at 1.1 scfm; O_2/CO_2/TVH/He measurements taken for 7 hrs following injection.

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Table 3.7
Surface Air Emissions at
Fuel Storage Area G (Site 1)
Travis AFB, California

Location[1]	Distance from VW−1 (ft)	Before Air Injection	After Air Injection
		TVH concentrations in ppmv	
NW1	6.5	11	80[2]
NW2	13.0	2	0
NW3	19.5	0	0
S1	6.5	0	8[2]
S2	13.0	6	0
S3	19.5	3	0
NE1	6.5	3	21[2]
NE2	13.0	0	2
NE3[3]	19.5	11	24[2]

LEGEND

TVH: Total volatile hydrocarbons (field instrument)
[1]: NW=northwest of VW−1
S=south of VW−1
NE=northeast of VW−1
[2]: average of fluctuating reading
[3]: location is above an underground fuel tank

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surface, an injected flow rate of 14 scfm, and an emission level of 69 ppmv (the largest increase measured at the surface monitoring points).

It is anticipated that long-term emissions at this pilot test site will also be negligible as the volatilization component of degradation will quickly decline with time and accumulated hydrocarbon vapors in the soil will move slowly outward from the air injection point and will be biodegraded as they move horizontally through the soil.

3.2.6 Recommendations

Initial bioventing tests at the Fuel Storage Area G (Site 1) indicate that oxygen has been depleted in the contaminated soils, and that air injection is an effective method of increasing aerobic biodegradation of fuel. The Air Force Center for Environmental Excellence (AFCEE) has recommended that air injection be implemented at this site to determine the long-term radius of oxygen influence and the effect of time, available nutrients, and changing soil temperatures on fuel biodegradation rates.

A small, 1.0-horsepower Gast™ regenerative blower has been installed at Site 1 to continue air injection. In December 1993, ES personnel will return to the site to sample and analyze the soil gas and conduct a second respiration test. In June 1994, a final respiration test will be conducted, and soil and soil-gas samples will be collected from the site to determine the degree of remediation achieved during the first year of *in situ* treatment.

Based on results presented by ES for the first year of pilot-scale bioventing, AFCEE will recommend one of two options:

1. Upgrade, if necessary, and continue operation of the bioventing system for full-scale remediation of the site. AFCEE can assist the base in obtaining regulatory approval for upgrading and continued operations.
2. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE may recommend removal of the blower system and proper abandonment of the VW and VMPs.

4.0 EXPANDED PILOT TEST DESIGN FOR SOUTH GAS STATION (SGS) SITE

4.1 Concept of Operations

4.1.1 Summary of Initial Testing

Initial pilot testing at the SGS site has indicated that the soils at the site are permeable to air flow and that oxygen can be distributed at distances of at least 25 feet from the vent wells. *In situ* respiration testing has measured fuel biodegradation rates of 2,600 to 5,300 mg fuel/kg of soil per year (7.1 to 14.5 mg fuel/kg soil per day) when oxygen is provided to the contaminated soils at this site. Analysis of soil gas indicates that total volatile hydrocarbons as gasoline (TVH-g) concentrations of 140,000 to 150,000 ppmv exist beneath the asphalt areas of the site. However, TVH-g levels decreased rapidly from 140,000 ppmv to 35,000 ppmv and benzene levels decreased rapidly from 1,800 ppmv to 420 ppmv at the vapor extraction well (VEW-1) following two hours of soil vapor extraction during initial pilot testing. No floating product was measured at the site during the most recent site visit on 10 June 1993, indicating that this long-term source of contamination is decreasing.

4.1.2 Phase One - Soil Vapor Extraction Operations

The first phase of the expanded pilot test will focus on removing the initial high levels of volatile hydrocarbons from the soil through use of a soil vapor extraction (SVE) system with off gas treatment provided by an internal combustion engine and a catalytic converter. The SVE system will be attached to the two vapor extraction wells (VEW-1 and VEW-2) through subsurface PVC piping, and flow control valves will be used to control flow between the two wells (Figure 4.1).

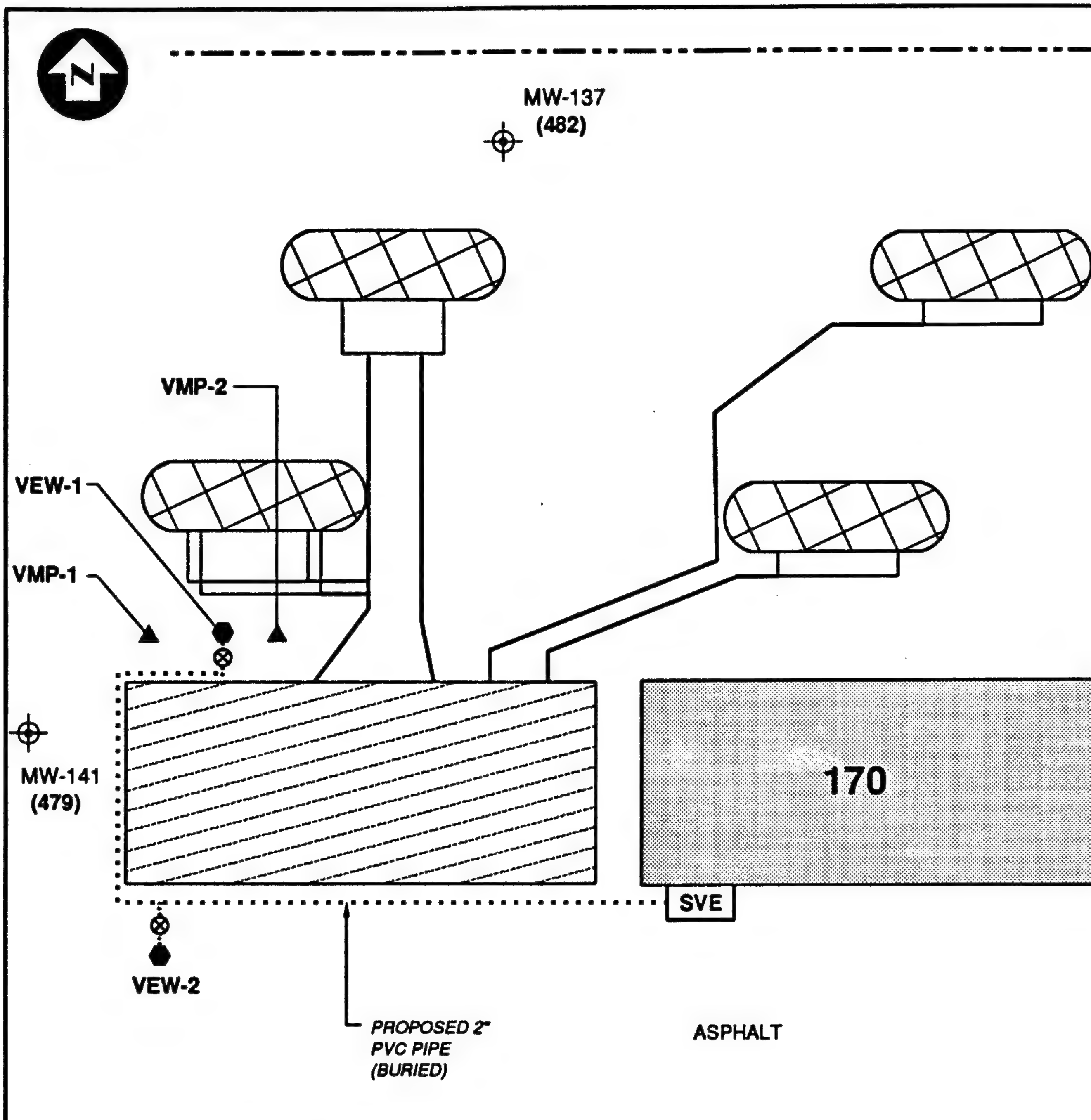
The SVE system will be operated to achieve mass removal of at least 90% by wt. of influent TVH and benzene concentrations, as required by the Bay Area Air Quality Management District (BAAQMD). System monitoring is discussed in more detail in Section 4.3.

Based on a conservative fuel biodegradation rate of 5 mg fuel/kg soil per day, the estimated soil volume of 40,000 ft^3 within the radius of influence of the two vent wells, and a flow rate of 20 scfm, *in situ* biodegradation of 3,000 ppmv TVH-g can be sustained by an air injection bioventing system. Therefore, Phase One SVE operations will continue until influent concentrations are at or below 3,000 ppmv TVH-g and then Phase Two bioventing operations will begin.

The total duration of Phase One is expected to be 60 to 90 days, based on performance of SVE systems at similar sites.

4.1.3 Phase Two - Bioventing Operations

Phase Two of the expanded pilot test will focus on the *in situ* biodegradation of the remaining fuel residuals in the soil. Based on initial pilot test results, an air injection rate of 10 scfm at both vent wells (20 scfm total) should be sufficient to supply oxygen to 40,000 ft^3 of contaminated soil at the SGS site. Potential atmospheric air emissions



EXPLANATION

170	STRUCTURE	VMP-1	VAPOR MONITORING POINT
	UST COMPLEX	VEW-1	VAPOR EXTRACTION WELL
	GAS PUMP ISLAND	⊗	FLOW CONTROL VALVE
	PRODUCT PIPELINE	SVE	PROPOSED LOCATION FOR SOIL VAPOR EXTRACTION SYSTEM
	SITE BOUNDARY		
MW-141 (479)	EXISTING MONITORING WELL WITH ID NUMBER (FORMER SOIL BORING)		

PROPOSED SUBSURFACE PIPING AND SVE SYSTEM LOCATION

TRAVIS AIR FORCE BASE, CALIFORNIA

REV. 2 C250-44.DWG 09/02/93

ENGINEERING-SCIENCE, INC.

should be negligible because of the asphalt surface covering within the radius of influence of the two vent wells, preventing vertical soil vapor flow, and Phase One operations will have removed the majority of hydrocarbon vapors. In addition, any remaining hydrocarbon vapors will be biodegraded as they move horizontally through the soil.

During Phase Two operations, air monitoring using a PID and a THVA will be performed within surrounding buildings and along any subsurface utilities to verify that hazardous levels of vapors are not migrating from the site. Since all surrounding buildings are beyond the expected 25 foot radius of influence from the vent wells and there are no basements in the surrounding buildings, vapor migration is not expected to be a problem at the site. In addition, the low flow rates and the target soil gas level of 3,000 ppmv TVH-g, which is approximately 20% of the lower explosive limit (LEL) for gasoline, further minimize the potential for producing hazardous levels of vapors at the site.

4.2 Overview of System Design

4.2.1 Phase One - Soil Vapor Extraction (SVE) System

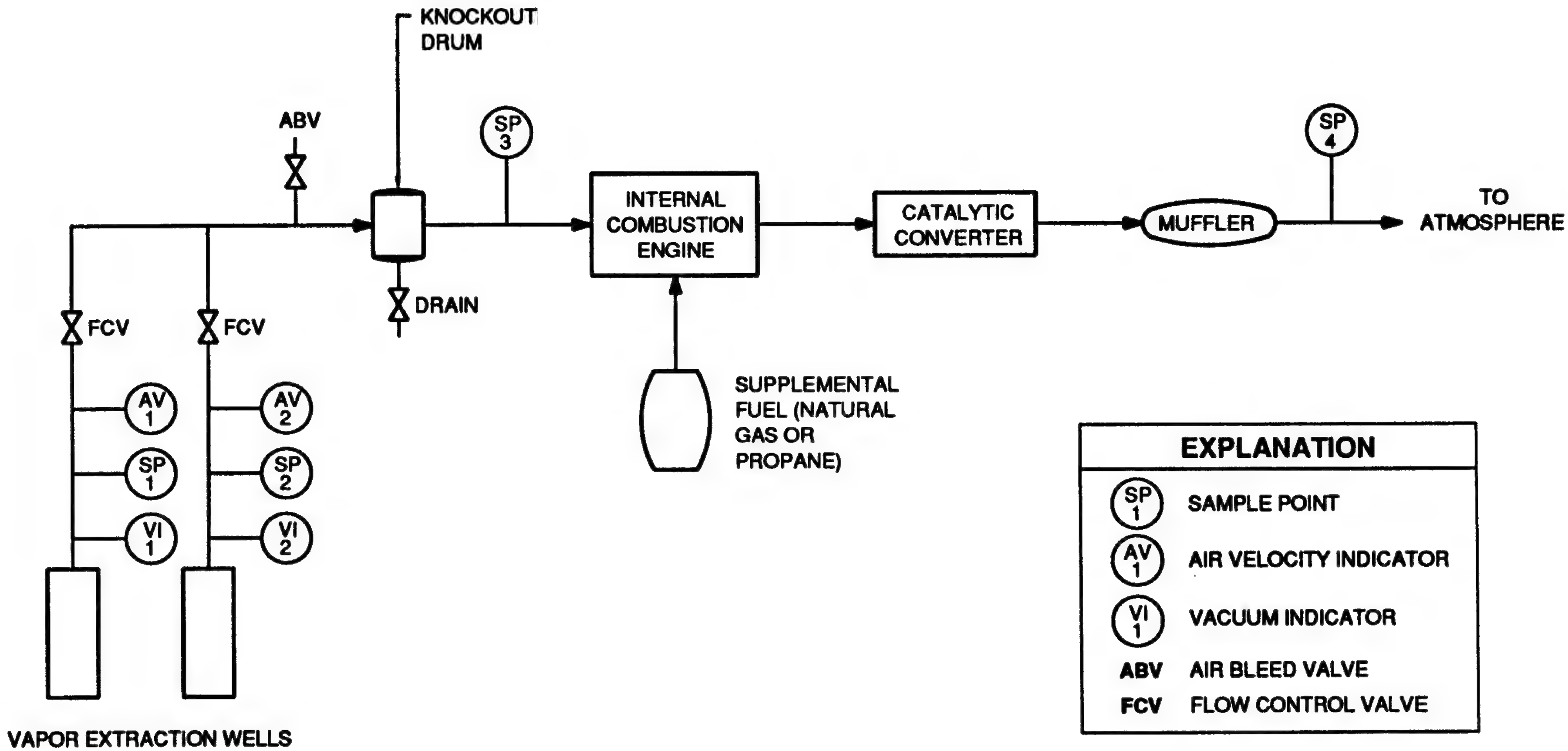
The SVE system proposed for use at the SGS site is manufactured by Remediation Service, International (RSI) of Oxnard, California and has been designed to remediate petroleum contaminated soils while maintaining strict California air emission standards. A process and instrumentation diagram is shown in Figure 4.2 and Appendix E contains detailed information on the system provided by the manufacturer. This system has been permitted within the State of California at similar sites; however, a site-specific air permit will be required by the BAAQMD.

An internal combustion engine is used as a source of vacuum to draw soil vapor from the extraction wells into the intake manifold of the engine. The soil vapor is then combusted within the engine, with propane or natural gas used as a supplemental fuel during startup or when hydrocarbon levels in the soil gas are insufficient to keep the engine operating smoothly. The exhaust gas is then passed through a catalytic converter to ensure maximum reduction of hydrocarbons. On-board system analyzers ensure that engine parameters are adjusted properly and that emissions are minimized. No external power source is required.

The SVE system will be sized to deliver a flow rate of up to 60 scfm (total flow from both vent wells) at the expected well head pressure of approximately 5 psi (10 in. Hg), which was measured during the initial pilot test at a flow rate of approximately 25 scfm from a single vent well. A system of this size will remove up to approximately 10 lbs/hr of hydrocarbons at a destruction efficiency exceeding 99%, based on performance at similar sites. Actual operating parameters will be dependent on soil conditions, hydrocarbon concentrations in the extracted soil gas, air emissions requirements, and engine performance.

The system requires minimal maintenance, consisting primarily of resupplying the supplemental fuel tanks and monitoring system performance. The system is trailer-mounted for ease of transportation and setup.

FIGURE 4.2



PROCESS FLOW AND INSTRUMENTATION DIAGRAM SOIL VAPOR EXTRACTION

TRAVIS AIR FORCE BASE, CALIFORNIA

REV. 1 C250-45.DWG 09/01/93

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4.2.2 Phase Two - Bioventing System

Following completion of SVE operations, an air injection bioventing system will be installed at the site. The system will be similar to that installed at Fuel Storage Area G (Site 1) and described in Part I, Section 3.8. The system will be connected to the two vent wells (VEW-1 and VEW-2) through the same subsurface PVC piping used for SVE operations. Flow control valves will remain in place so that air flow can be controlled between the two wells.

Based on the radius of influence calculated from data collected during the initial pilot test, site soil conditions, and the expected decrease in well head pressure at the vent wells due to the lower flow rate, a 1.0-horsepower Gast™ regenerative blower (model R4) capable of operating at 20 scfm at a well head pressure of 50" H_2O will be installed at the site. This flow rate should be sufficient to aerate the soils within a 25 foot radius of both vent wells and is low enough to minimize potential vapor migration.

4.3 System Monitoring and Evaluation

4.3.1 Air Monitoring Plan (Phase One - SVE Operations)

During Phase One SVE operations, soil gas entering and exiting the SVE system will be analyzed for both TVH-g and BTEX by EPA Method TO-3 using procedures similar to those described in Part I, Section 3.3.2. These results will be used to tune the SVE system to achieve maximum removal rates, while remaining below air emissions levels required by the BAAQMD. When results of soil gas analysis indicate that contaminant levels are at or below 3,000 ppmv TVH-g, the SVE system will be shut down and Phase Two bioventing operations will begin.

Oxygen, carbon dioxide, and TVH (using the THVA) will also be measured in the SVE influent and at all VMPs in order to screen soil gas samples for laboratory analysis and verify that oxygen levels in soils increase as a result of SVE operations.

Table 4.1 provides a summary of the frequency and type of monitoring to be conducted at each monitoring location during Phase One operations. Monitoring will be most intense during system startup when the highest levels of volatile hydrocarbons will be extracted from the soil and performance of the SVE system is being evaluated. Monitoring will then continue on a periodic basis until the target level of 3,000 ppmv TVH-g is reached.

4.3.2 Air Monitoring Plan (Phase Two - Bioventing Operations)

The biodegradation of fuel residuals in the soil will be monitored using an *in situ* respiration test similar to that described in Part I, Section 3.6. Tests will be conducted after six months and one year of operation. These tests will determine how the activity of microorganisms at various points in the contaminated soil volume changes over time and as contamination levels decrease.

A PID and THVA will also be used initially within surrounding buildings and along any subsurface utilities to verify that hazardous levels of vapors are not migrating.

TABLE 4.1

MONITORING SCHEDULE (PHASE ONE- SVE OPERATIONS)

Location	Analysis	Frequency
SVE Influent	TVH-g, BTEX (EPA TO-3)	Daily for first three days Weekly thereafter
	O_2 /CO_2/TVH (field)	Daily for first three days Weekly thereafter
SVE Effluent	TVH-g, BTEX (EPA TO-3)	Daily for first three days Weekly thereafter
SVE System	Flow rate temperature (inlet/outlet) auxiliary fuel use	Daily for first three days Weekly thereafter
VMPs	O_2/CO_2 /TVH (field)	Daily for first three days Weekly thereafter

4.3.3 One Year Evaluation

At the end of one year of operation of the air injection bioventing system, ES personnel will return to the site to sample and analyze the soil gas, conduct a final respiration test, and collect soil samples to determine the degree of remediation achieved during the first year of operation. Based on results presented by ES for the first year of pilot-scale bioventing, AFCEE will recommend one of two options:

1. Upgrade, if necessary, and continue operation of the bioventing system for full-scale remediation of the site. AFCEE can assist the base in obtaining regulatory approval for upgrading and continued operations.
2. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE may recommend removal of the blower system and proper abandonment of the wells.

5.0 BASE SUPPORT REQUIREMENTS

The following base support is needed prior to the arrival of the soil vapor extraction (SVE) system:

- Obtaining all necessary regulatory permits for the SVE system, most importantly the air permit which will be required by the Bay Area Air Quality Management District (BAAQMD) before extraction operations can proceed.
- Obtaining a base digging permit for installation of the subsurface PVC piping from the vent wells to the proposed location of the SVE system and bioventing blower (see Figure 4.1).
- Obtaining any other needed permissions from base and site personnel to conduct subsurface trenching, bioventing, and SVE operations.

During the Phase One SVE operations (expected to last 60 to 90 days) and during the Phase Two bioventing operations (one year), the following base support is required:

- During Phase One, base personnel are to check the SVE system once each week to ensure that it is operating properly, record system monitoring information, and notify ES if the supplemental fuel needs to be resupplied. ES will provide a brief training session.
- During Phase Two, base personnel are to check the bioventing system once each week to ensure that it is operating properly and record system monitoring information. Monitoring data must be transmitted to ES once each month. ES will provide an operations manual and a brief training session.
- If the SVE system (during Phase One) or the bioventing blower (during Phase Two) stops working, notify: Mr. Fred Stanin or Mr. Michael Phelps, ES-Alameda, (510) 769-0100; or Mr. Doug Downey, ES-Denver (303) 831-8100; or Mr. Sam Taffinder of AFCEE, (210) 536-4366.
- Arrange for site access for ES technicians to conduct Phase One operations (see Table 4.1) and Phase Two operations including *in situ* respiration tests at approximately six months and one year after the initiation of Phase Two bioventing operations.

6.0 PROJECT SCHEDULE

The following schedule is contingent upon timely approval of the SVE system design, obtaining the required air permit for SVE operations, and the estimate of 60 to 90 days for Phase One operations.

Event	Date
Interim Results Report to AFCEE/Travis AFB	23 Sep 1993
Approval to Proceed	15 Oct 1993
Begin subsurface trenching operations	18 Oct 1993
Begin Phase One SVE operations	25 Oct 1993
Begin Phase Two bioventing operations	January 1994
Biannual Respiration Tests	July 1994
Final Respiration Tests and Soil Sampling	January 1995

7.0 REFERENCES

Deyo, B.G., et al. 1993, Use of Portable Oxygen and Carbon Dioxide Detectors to Screen Soil Gas for Subsurface Gasoline Contamination; Groundwater, Volume 31, Number 4. July-August

Earth Technology 1992, Technical memorandum. Installation Restoration Program, JP-4 Removal Investigation, Travis AFB, California. April

Hinchee et al. 1992, Test Plan and Technical Protocol for a Field Treatability Test for Bioventing, U.S. Air Force Center for Environmental Excellence (AFCEE). January

Schwille, F. 1976, Antropogenically Reduced Groundwaters; Hydrological Sciences-Bulletin, Volume 21, Number 4, pp 629-645

APPENDIX A

GEOLOGIC BORING LOGS

ES ENGINEERING-SCIENCE

BOREHOLE NUMBER: 1 (VMP-1)

PROJECT NUMBER: DE 268.21.04	**PROJECT NAME:** BIOVENTING INITIATIVE
CLIENT: AFCEE	**DRILLER:** GREGG DRILLING
LOCATION: TRAVIS AFB, CA	**DRILLING METHOD:** HOLLOW-STEM AUGER
SOUTH GAS STATION SITE	
GEOLOGIST: HENRY PIETROPAOLI	**HOLE DIAMETER:** 8 INCHES
COMPLETION DATE: 9 DEC 92	**TOTAL DEPTH:** 15.5 FT. BGS

DEPTH feet	SAMPLE LOCATION	SAMPLE NUMBER	BLOW COUNT	PID (ppm) [THYA] (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
0							Asphalt (4"@surface); Road Rk (8")
							SILT: clayey, discolored blue-grn, damp, plastic, mod stiff, fuel odor.
5			3/4/4	26 [4]			A/A, with more clay.
10							A/A, w/gradational color change from blue-grn to brown.
			8/12/16	2342 [2200]			SAND: fine, well sorted, loose; gradational contact to discolored green sand.
15		TRsgs-VMP1-15.5	8/10/15	1580 [380]			

▼ - Equilibrated waterlevel.

▽ - First encountered groundwater.

█ - Brass tube sample submitted for laboratory analysis

jm2

ES ENGINEERING-SCIENCE

BOREHOLE NUMBER: 2 (VEW-1)

PROJECT NUMBER:	DE 268.21.04	**PROJECT NAME:**	BIOVENTING INITIATIVE
CLIENT:	AFCEE	**DRILLER:**	GREGG DRILLING
LOCATION:	TRAVIS AFB, CA	**DRILLING METHOD:**	HOLLOW-STEM AUGER
	SOUTH GAS STATION SITE		
GEOLOGIST:	HENRY PIETROPAOLI	**HOLE DIAMETER:**	10 INCHES
COMPLETION DATE:	9 DEC 92	**TOTAL DEPTH:**	15.5 FT BGS

DEPTH feet	SAMPLE LOCATION	SAMPLE NUMBER	BLOW COUNT	PID (ppm) [THVA] (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
							Asphalt and road rock
							CLAY: dk gry-brn, mod stiff, plastic, moist, fuel odor.
5			3/5/5	1122 [79]			
							color change to blue-gray.
10			NR	152 [0]			
			NR	1423 [560]			CLAY: silty, red-brn, soft, sli damp. fuel odor.
			NR	2272 [1800]			SAND: brn, w/some discoloration, loose, damp, mod-well sort, discoloration is greenish fuel odor.
15		TRsgs-VEW1-15.5	NR	3104 [400]			

▼ - Equilibrated waterlevel.

▽ - First encountered groundwater.

█ - Brass tube sample submitted for laboratory analysis

NR = Not Recorded

jm2

ES ENGINEERING-SCIENCE

BOREHOLE NUMBER: 3 (VMP-2)

PROJECT NUMBER: DE 268.21.04	**PROJECT NAME:** BIOVENTING INITIATIVE
CLIENT: AFCEE	**DRILLER:** GREGG DRILLING
LOCATION: TRAVIS AFB, CA	**DRILLING METHOD:** HOLLOW-STEM AUGER
SOUTH GAS STATION SITE	
GEOLOGIST: HENRY PIETROPAOLI	**HOLE DIAMETER:** 8 INCHES
COMPLETION DATE: 9 DEC 92	**TOTAL DEPTH:** 15.5 FT. BGS

DEPTH feet	SAMPLE LOCATION	SAMPLE NUMBER	BLOW COUNT	PID (ppm) [THVA] (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
							Asphalt (at surf – 4"); road rock – 8"
							CLAY: dk grn-brn, plastic, mod stiff, damp, black streaks.
5			3/4/7	2713 [280]			
							CLAY: A/A, with silt, color change to yellowish red-brn.
10			7/8/16	1872 [110]			
							CLAY: Silty, gradational change to blue-grn discoloration, fuel odor.
15		TRsgs-VMP2-15.5	4/6/7	3218 [26]			▽ 15.5

- Equilibrated waterlevel.
- First encountered groundwater.
- Brass tube sample submitted for laboratory analysis

jm2

ES ENGINEERING-SCIENCE

BOREHOLE NUMBER: 4 (VEW-2)

PROJECT NUMBER: DE 268.21.04	**PROJECT NAME:** BIOVENTING INITIATIVE
CLIENT: AFCEE	**DRILLER:** GREGG DRILLING
LOCATION: TRAVIS AFB, CA	**DRILLING METHOD:** HOLLOW-STEM AUGER
SOUTH GAS STATION SITE	
GEOLOGIST: HENRY PIETROPAOLI	**HOLE DIAMETER:** 10 INCHES
COMPLETION DATE: 10 DEC 92	**TOTAL DEPTH:** 15.5 FT. BGS

DEPTH feet	SAMPLE LOCATION	SAMPLE NUMBER	BLOW COUNT	PID (ppm) [THVA] (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
0							ASPHALT (at surf-6"); sdy gvl (8")
							CLAY: silty, discolored (lgt green-gray), damp, plastic, stiff, fuel odor.
5			5/6/7	40 [0]			
10			7/12/16	51 [9]			CLAY: A/A, no discoloration, green to lgt yel-brn, stiff, damp, plastic, minor organics.
				2057 [1600]			SAND: med grd, silty, lgt brn, damp, loose, mod-well sorted, green discoloration, heavy fuel odor.
15			4/6/7	3075 [1800]			▽ 15.5

- Equilibrated waterlevel.
- First encountered groundwater.
- Brass tube sample submitted for laboratory analysis

jm2

ES ENGINEERING-SCIENCE

BOREHOLE NUMBER: 5 (VMP-3)

PROJECT NUMBER: DE 268.21.04	**PROJECT NAME:** BIOVENTING INITIATIVE
CLIENT: AFCEE	**DRILLER:** GREGG DRILLING
LOCATION: TRAVIS AFB, CA	**DRILLING METHOD:** HOLLOW-STEM AUGER
SOUTH GAS STATION SITE	
GEOLOGIST: HENRY PIETROPAOLI	**HOLE DIAMETER:** 8 INCHES
COMPLETION DATE: 10 DEC 92	**TOTAL DEPTH:** 20.0 FT. BGS

DEPTH feet	SAMPLE LOCATION	SAMPLE NUMBER	BLOW COUNT	PID (ppm) [THVA] (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
							LAWN SOIL : dk brn, organic
5			15/12/14	2.6 [0]			CLAY: lgt tan to white w/ green-gray, hard, sli plastic, damp, w/ orange-brn streaking/staining, minor organics. Appears to be a volcanic ash/clay.
10			21/26/33	3.0 [0]			CLAY: silty (high fraction), very hard. Rest A/A.
15			19/32/34	6 [0]			CLAY: A/A, very hard/tight, orange-brn Fe stains in fractures.
							SILT: clayey, sm silty clay, abnd Fe staining in patches and in fractures, hard, stiff, sli plastic, dry to damp.
20			50	16.2 [0]			SAND: fine, silty, yellow-brn, med dense, mod-well sort, dry to damp, grades down to a friable SANDSTONE at 19.0' bgs.

- Equilibrated waterlevel.

- First encountered groundwater.

- Brass tube sample submitted for laboratory analysis

jm2

Sheet 1 of 1

ES ENGINEERING-SCIENCE

BOREHOLE NUMBER: 1 (VW-1)

PROJECT NUMBER: DE 268.21.04	**PROJECT NAME:** BIOVENTING INITIATIVE
CLIENT: AFCEE	**DRILLER:** GREGG DRILLING
LOCATION: TRAVIS AFB, CA	**DRILLING METHOD:** HOLLOW-STEM AUGER
Fuel Storage Area 6 (IRP Site 1)	
GEOLOGIST: HENRY PIETROPAOLI	**HOLE DIAMETER:** 10 INCHES
COMPLETION DATE: 18 FEB 93	**TOTAL DEPTH:** 12.0 FT BGS

DEPTH feet	SAMPLE LOCATION	SAMPLE NUMBER	BLOW COUNT	PID (ppm) (TVHA) (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
0							Gravel / Drain Rock
0–2.1							CLAY: Silty, dk brn, damp, stiff, sli plastic.
2–3	sample interval			160 (152)			
2.1–10							SILT: clayey to fine SAND, yellow to green-brown w/ blue-black streaks, stiff, sli. plastic, damp, micaceous, fuel odor.
5–6.5	brass tube sample (≈5.5–6.5)	TR1-VEW1-6		114 (38)			
7							Predominantly fine grd SAND
7.7							▼ 7.7'
8.3							▽ 8.3'
8–9.5	sample interval			1680 (2700)			
10–12							SAND: clayey, med-fine grd, blue-green (discolored?), sli plastic, mod stiff, fuel odor.

▼ - FREE-PRODUCT [redacted]

▽ - First encountered groundwater.

▮ - Brass tube sample submitted for laboratory analysis

jm2

ES ENGINEERING-SCIENCE

BOREHOLE NUMBER: 2 (VMP-1)

PROJECT NUMBER: DE 268·21·04	**PROJECT NAME:** BIOVENTING INITIATIVE
CLIENT: AFCEE	**DRILLER:** GREGG DRILLING
LOCATION: TRAVIS AFB, CA	**DRILLING METHOD:** HOLLOW-STEM AUGER
Fuel Storage Area G (IRP Site 1)	
GEOLOGIST: HENRY PIETROPAOLI	**HOLE DIAMETER:** 8 INCHES
COMPLETION DATE: 18 FEB 93	**TOTAL DEPTH:** 12.0 FT. BGS

DEPTH feet	SAMPLE LOCATION	SAMPLE NUMBER	BLOW COUNT	PID (ppm) [THVA] (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
0							Gravel / Drain Rock
1							CLAY: Silty, dark brn, damp, stiff, plastic.
2				124			
3				[88]			SILT: Clayey, green-brown, damp, stiff, sli plastic, fuel odor.
4							
5				328			SILT: A/A, except yellow-brown.
6		TR1-VMP1-6		(240)			SILT: A/A, except green-brown, fuel odor.
7							
8				1680			▼ 7.7' ▽ 8.4' SAND: Fine grd, clayey, to SILT. Blue-green, sli plastic, mod stiff, fuel odor.
9				(2400)			
10							
11							
12							

▼ - FREE-PRODUCT [redacted]

▽ - First encountered groundwater.

█ - Brass tube sample submitted for laboratory analysis

jm2

ES ENGINEERING-SCIENCE

BOREHOLE NUMBER: 3 (VMP-2)

PROJECT NUMBER: DE 268.21.04	**PROJECT NAME:** BIOVENTING INITIATIVE
CLIENT: AFCEE	**DRILLER:** GREGG DRILLING
LOCATION: TRAVIS AFB, CA	**DRILLING METHOD:** HOLLOW-STEM AUGER
Fuel Storage Area G (IRP Site 1)	
GEOLOGIST: HENRY PIETROPAOLI	**HOLE DIAMETER:** 8 INCHES
COMPLETION DATE: 18 FEB 93	**TOTAL DEPTH:** 12.0 FT BGS

DEPTH feet	SAMPLE LOCATION	SAMPLE NUMBER	BLOW COUNT	PID (ppm) (THVA) (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
0							Gravel / Drain Rock
0–2							CLAY: Silty, dark brown to black, stiff, sli plastic, damp.
2–4	2–3			784 (180)			SILT: Clayey, green-brown, stiff, plastic, damp, blue-gray streaks, fuel odor.
4–7	5–6.5	TR1-VMP2-6		1076 (46)			SILT: clayey, green-brown, mod stiff, sli plastic, damp, blue-gray streaks, fuel odor.
7–12	8–9.5	TR1-VMP2-9		1198 (52)		▼ 7.9' ▽ 8.8'	SAND: fine to med grained, clayey, sli plastic, stiff to loose, damp, fuel odor.

▼ - FREE-PRODUCT

▽ - First encountered groundwater.

█ - Brass tube sample submitted for laboratory analysis

NOTE: THVA Readings suspected to be low due to weak battery.

jm2

ES ENGINEERING-SCIENCE

BOREHOLE NUMBER: 4 (VMP-3)

PROJECT NUMBER: DE 268.21.04	**PROJECT NAME:** BIOVENTING INITIATIVE
CLIENT: AFCEE	**DRILLER:** GREGG DRILLING
LOCATION: TRAVIS AFB, CA	**DRILLING METHOD:** HOLLOW-STEM AUGER
Fuel Storage Area G (IRP Site 1)	
GEOLOGIST: HENRY PIETROPAOLI	**HOLE DIAMETER:** 8 INCHES
COMPLETION DATE: 18 FEB 93	**TOTAL DEPTH:** 12.0 FT. BGS

DEPTH feet	SAMPLE LOCATION	SAMPLE NUMBER	BLOW COUNT	PID (ppm) (THVA) (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
0							Gravel / Drain Rock
0–1.5							CLAY: Silty, dark brown, damp, plastic, mod stiff
2–3	2–3			78 [NR]			Silty CLAY to Clayey SILT: yellow-green, mod stiff, plastic, damp, blue-grey streaks, fuel odor.
5–6	5–6			490 [NR]			
7–8							SAND: Fine to med grained, blue-gray, loose, sli plastic, moist, fuel odor. 7.8' 8.8'
8–9	8–9			1269 [NR]			
10.5–11							CLAY: Sandy (med), blue-gray, moist, plastic
11–12							SAND: Clayey, fine-med, blue-gray, moist, sliplastic, fuel odor.

▼ - FREE PRODUCT

▽ - First encountered groundwater.

█ - Brass tube sample submitted for laboratory analysis

NOTE: THVA Readings not recorded due to dead battery.

jm2

ES ENGINEERING-SCIENCE

BOREHOLE NUMBER: 5 (VMP-4)

PROJECT NUMBER: DE 268.21.04	**PROJECT NAME:** BIOVENTING INITIATIVE
CLIENT: AFCEE	**DRILLER:** GREGG DRILLING
LOCATION: TRAVIS AFB, CA	**DRILLING METHOD:** HOLLOW-STEM AUGER
Fuel Storage Area G (IRP Site 1)	
GEOLOGIST: HENRY PIETROPAOLI	**HOLE DIAMETER:** 8 INCHES
COMPLETION DATE: 18 FEB 93	**TOTAL DEPTH:** 12 FT BGS.

DEPTH feet	SAMPLE NUMBER	BLOW COUNT	PID (ppm) [THVA] (ppm)	SOIL CLASS	GEOLOGIC DESCRIPTION
0–1					Topsoil — abundant organics
1–3.2			145 [0]		CLAY: med-gray/brn, soft, damp, plastic
3.2–5					CLAY: silty, light yellow-brown, mod stiff, plastic, damp w/ organics (common).
5–9	TR1-VMP4-6		24 [0]		CLAY: silty to sandy (fine), yellow-brown, damp, plastic, mod stiff.
9–11.5			11 [0]		CLAY: silty, yellow-brown, damp, sli plastic, mod stiff.
11.5–12			19 [2]		▽ 11.5' SAND: fine grd, clayey, yellow-brown, damp to moist, mod stiff, sli plastic.

▼ - ~~[illegible]~~ FREE PRODUCT

▽ - First encountered groundwater.

■ - Brass tube sample submitted for laboratory analysis

jm2

APPENDIX B

O&M MANUAL AND DATA COLLECTION SHEET

GENERIC BLOWER SYSTEM OPERATIONS AND MAINTENANCE MANUAL FOR EXTENDED PILOT TESTING SYSTEM

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE

BROOKS AFB, TEXAS

USAF CONTRACT F33615-90-D-4010, DELIVERY ORDER 14

April 1993

Prepared by:

Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado

A7-15-43

CONTENTS

FIGURES

SECTION 1

INTRODUCTION

This document has been prepared by Engineering-Science, Inc. to support the bioventing initiative contract awarded by the Air Force Center for Environmental Excellence. The contract involves the conducting of bioventing pilot tests at 35 sites on 23 Air Force bases across the United States.

At most sites, bioventing systems will be installed upon completion of the initial bioventing pilot tests for the purpose of extended pilot testing. These systems will operate for a 1-year period to provide further information as to the feasibility of the technology at each site, and to provide interim remedial action.

This Operations and Maintenance Manual has been created for sites at which regenerative or rotary-vane blowers have been installed for extended pilot testing. Basic maintenance of these systems is the responsibility of the Air Force facility. This manual is to be used by facility personnel to guide and assist them in operating and maintaining the blower system. Section 2 provides a summary of the bioventing system components installed. Section 3 of this document describes the blower system. Section 4 details the maintenance requirements and provides maintenance schedules. Section 5 describes the system monitoring that is required to forecast system maintenance needs and to provide data for the extended pilot test. Blower performance curves and relevant service information for regenerative and rotary-vane blowers are provided in Appendices A and B, respectively, and data collection sheets are provided in Appendix C.

SECTION 2

BLOWER SYSTEM CONFIGURATION SUMMARY

System Type (injection, extraction) Injection

Blower (regenerative, rotary vane) Regenerative

Blower Model R4 110N-50

Motor (Hp) 1.0

Knock-Out Chamber (yes, no) No

Sampling Port (yes, no) No

Inlet Temperature Gauge (range) not installed

Inlet Pressure/Vacuum Gauge (range) 0-60 "H_2O

Inlet Filter (part no.) F-30P-150

Outlet Temperature Gauge (range) 0-250 °F

Outlet Pressure/Vacuum Gauge (range) 0-100 "H_2O

Pressure/Vacuum Relief Valve Set @ (give unit of measure) 50 " H_2O

SECTION 3

BIOVENTING SYSTEM OPERATION

3.1 PRINCIPLE OF OPERATION

Bioventing is the forced injection of fresh air, or withdrawal of soil gas, to enhance the supply of oxygen for *in situ* bioremediation. Either a pressure (air injection) or vacuum (vapor extraction) blower unit is used to inject or withdraw air into or from the soil, thereby supplying fresh air with 20.8 percent oxygen to the contaminated soils. Once oxygen is provided to the subsurface, existing bacteria will proceed with the breakdown of fuel residuals.

At Fuel Storage Area G a air injection blower system has been installed.

3.2 SYSTEM DESCRIPTION

3.2.1 Blower System

A regenerative blower powered by a 1.0 horsepower direct-drive motor is the workhorse of the bioventing system. This blower is rated at a flow rate of 60 standard cubic feet per minute (scfm) at a pressure of 30 " H_2O ; however, the actual performance of the blower will vary with changing site conditions. As installed, the blower was producing an estimated flow rate of 15 scfm at a pressure of 45 " H_2O.* Vapor extraction systems may include an inlet knockout chamber for water condensation. All systems include an air filter to remove any particulates which are entrained in the air stream, and several valves and monitoring gauges which are described in the next section. A schematic of the blower system installed at Fuel Storage Area G is shown on Figure 3.1. Corresponding blower performance curves, and relevant service information are provided in Appendices A and B.

3.2.2 Monitoring Gauges

The bioventing system is equipped with vacuum and pressure gauges, temperature gauges, and a sampling port (vapor extraction only). Generally, gauges have been installed on the air injection system at the following locations: a vacuum gauge in the inlet piping and a pressure gauge in the outlet piping. For vapor extraction systems gauges are generally installed as follows: vacuum gauges in the

* actual flow into well; some flow is being bled off.

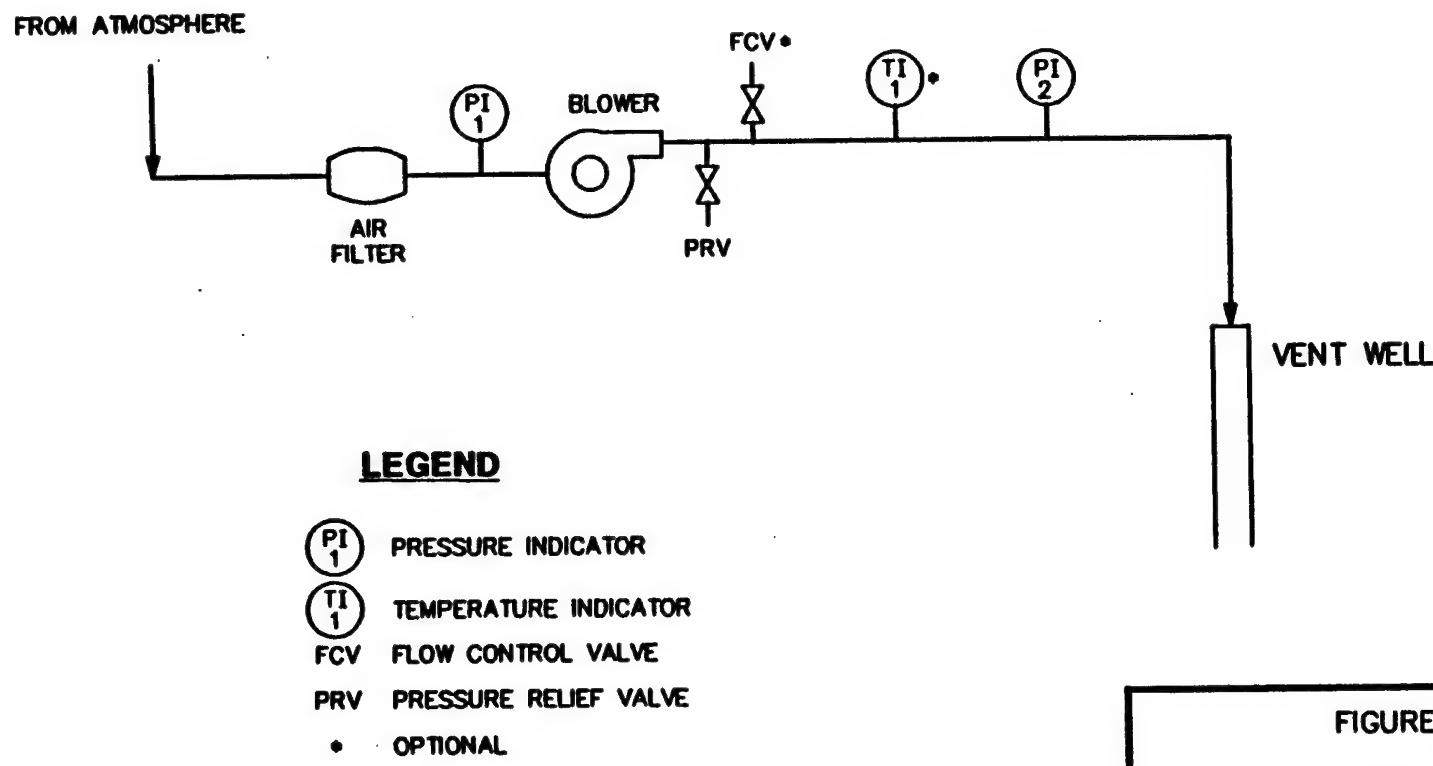


FIGURE 3.1

TYPICAL BLOWER SYSTEM INSTRUMENTATION DIAGRAM FOR AIR INJECTION

ENGINEERING-SCIENCE, INC.
Denver, Colorado

93DN0413, 04/05/93 at 12:54

inlet piping and at the knock-out chamber (as applicable), and a pressure gauge in the discharge piping. See Figure 3.1 for the locations of the gauges installed on the blower system at this site.

Temperature gauges may be located at the inlet and outlet of the blower system. These gauges are used to monitor the inlet and outlet temperature to determine the change in temperature across the blower. For air injection systems, ambient air temperature should be used when an inlet temperature gauge is not present. For vapor extraction systems, the inlet temperature is also used as an estimate of soil gas temperatures in the contaminated soil zone. See Figure 3.1 for the location(s) of the temperature gauges installed on the blower system at this site.

A sample port is located in the discharge piping on the outlet side of vapor extraction systems only. This sample port is used to collect offgas that is analyzed for carbon dioxide/oxygen and volatile organic compound concentrations. See Figure 3.1 for the location of the sampling port installed on the blower system at this site.

SECTION 4

SYSTEM MAINTENANCE

Although the motor and blower are relatively maintenance free, periodic system maintenance is required for proper operation and long life. Recommended maintenance procedures and schedules are described in detail in the instruction manuals included in Appendices A and B and briefly summarized in this section.

Filter inspection and knock-out chamber draining (as applicable) must be performed with the system turned off. ~~To re-start the motor, open the manual air dilution valve (red handle) to protect the motor from excessive strain, start motor~~, ~~and slowly close dilution valve. If the handle has been removed from the manual air dilution valve~~, do not open the valve or otherwise change the setting (it has been pre-set for a specific flow rate) before re-starting the blower. map

4.1 Blower/Motor

The blower and motor are relatively maintenance free and should not require any periodic maintenance during the 1-year extended testing period. Both blower and motor have sealed bearings and do not require lubrication.

4.2 KNOCK-OUT CHAMBER

This section applies only to vapor extraction systems equipped with moisture knock-out chamber. To avoid damage caused by passing liquids solids through the blower a knock-out chamber has been installed in-line before the blower.

Free liquid should not be pumped through the blower. The knock-out chamber installed in-line before the blower intercepts entrained liquid, preventing damage to the blower. The knock-out chamber should be drained into an appropriate container once a month for the first few months and at less frequent intervals thereafter, if it appears that this will be sufficient to keep liquid from building up in the knock-out chamber. Condensation generally increases during the cold winter months. A facility employee should determine the best schedule for draining the knock-out chamber. The knock-out chamber can be drained by turning the system off and removing the cap or opening the valve at the base of the knock-out chamber. When all of the liquid has drained out, the system can be turned back on. It is recommended when re-starting the system that the air dilution valve (red-handled valve) be opened to protect the motor from excessive strain. If oily, drained liquids should be disposed of in an oil/water separator.

4.3 AIR FILTER

To avoid damage caused by passing solids through the blower, an air filter has been installed in-line before the blower. The filter element is paper and is accompanied by a polyurethane foam prefilter. The filter should be checked weekly for the first 2 months of operation. Again, a facility employee should determine the best schedule for filter replacement. The polyurethane prefilters can be washed with lukewarm water and a mild detergent. Paper filter elements should never be washed, but should be disposed of and replaced as necessary. When the pressure or vacuum drop across the filter is above 15 inches of water, a dirty filter element should be suspected, and cleaning or replacement should be performed.

To remove the filter, loosen the three clamps or the wing nut, lift the metal top off the air filter, and lift the air filter from the metal housing. Remove the polyurethane prefilter (if applicable) and wash before replacing. When replacing the filter, be careful that the rubber seals remain in place.

The filter element is manufactured by Solberg Manufacturing, Inc. in Itasca, Illinois. Their telephone number is (708) 773-1363. Additional filters can also be obtained through Engineering-Science, Inc. in Denver, Colorado. The ES contacts are Mr. Brian Blicker and Mr. Robert Williams and they can be reached at (303) 831-8100. The filter model number is F-30P-150, and the number for the replacement element is 30P. It is recommended that EM office keep at least one spare air filter at the site, four spare filters were supplied with the blower system.

4.4 MAINTENANCE SCHEDULE

The following maintenance schedule is recommended for this system. During the initial months of operation more frequent monitoring is recommended to ensure that any startup problems are quickly corrected. A daily drive-by inspection is recommended during the initial 2 weeks of operation to ensure that the blower system is still operating with no unusual sounds. Data collection sheets that can be used to record maintenance activities are included in Appendix C.

Maintenance Item	Maintenance Frequency
Filter	Check once per month, wash or replace as necessary (see Section 4.3).
Knock-out chamber	Drain once per month initially, then periodically (see Section 4.2).

4.5 MAJOR REPAIRS

Blowers systems are very reliable when properly maintained. Occasionally, a motor or blower will develop a serious problem. If a blower system fails to start, and a qualified electrician verifies that power is available at the blower or starter,

the Engineering-Science, Inc. site manager Michael Phelps should be called at (510) 769-0100. ES is responsible for major repairs during the first year of operation.

SECTION 5

SYSTEM MONITORING

5.1 BLOWER PERFORMANCE MONITORING

To monitor the blower performance, vacuum, pressure, and temperature will be measured. These data should be recorded weekly on a data collection sheet (provided in Appendix C). All measurements should be taken at the same time while the system is running. Because the system is loud, hearing protection should be worn at all times.

5.1.1 Vacuum/Pressure

With hearing protection in place, open the blower enclosure and record all vacuum and pressure readings directly from the gauges (in inches of water or psi). Record the measurements on a data collection sheet (Appendix C).

5.1.2 Flow Rate

The flow rate through the vent well and soils can be calculated when the inlet vacuum and outlet pressure of the blower are known. This pressure change across the blower (vacuum + pressure) can be compared to the performance curves for the blower in Appendix A or Appendix B to determine the approximate flow rate.

5.1.3 Temperature

With hearing protection in place, open the blower enclosure and record the temperature readings directly from the gauges in degrees Fahrenheit (°F). Record the measurements on a data collection sheet (provided in Appendix C). The temperature change can be converted to degrees Celsius (°C) using the formula °C= (°F - 32) X 5/9.

5.3 MONITORING SCHEDULE

The following monitoring schedule is recommended for this system. During the initial months of operation, more frequent monitoring is recommended to ensure that any start up problems are quickly corrected. Data collection sheets have been provided to assist your data collection and are included in Appendix C.

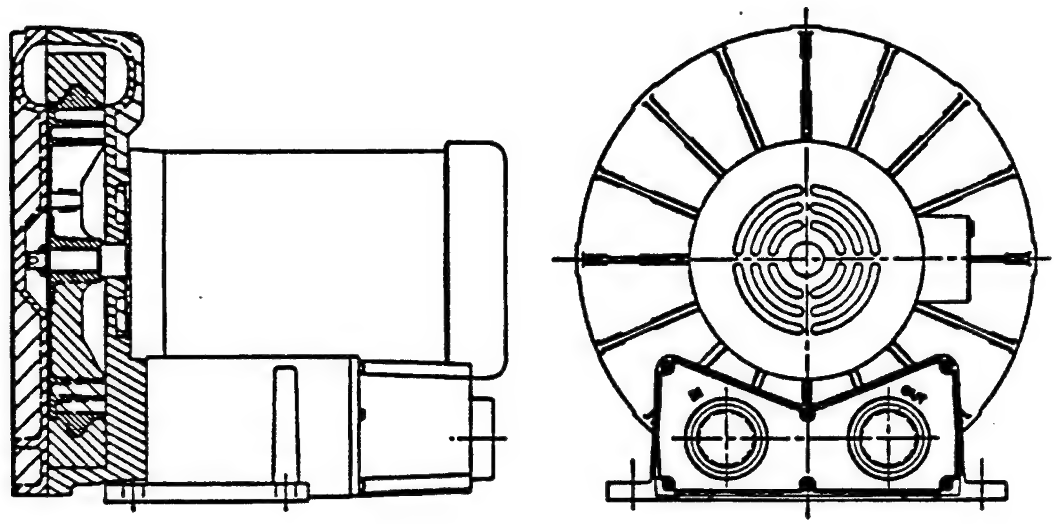
Monitoring Item	Monitoring Frequency
Vacuum/Pressure	Daily during first week, then once per week.
Temperature	Daily during first week, then once per week.

APPENDIX A
REGENERATIVE BLOWER INFORMATION

GAST

Post Office Box 97
Benton Harbor, Michigan 49023-0097
Ph: 616/926-6171
Fax: 616/925-8288

Maintenance Instructions for Gast Standard Regenerative Blowers



For original equipment manufacturers
special models, consult your local distributor

Gast Rebuilding Centers

Gast Mfg. Corp.
2550 Meadowbrook Rd.
Benton Harbor MI. 49022
Ph: 616/926-6171
Fax: 616/925-8288

Gast Mfg Corp.
505 Washington Avenue
Carlstadt, N. J. 07072
Ph: 201/933-8484
Fax: 201/933-5545

Brenner Fiedler. & Assoc.
13824 Bentley Place
Cerritos, CA. 90701
Ph: 213/404-2721
Fax: 213/404-7975

Wainbee, Limited
121 City View Drive
Toronto, Ont. Canada M9W 5A9
Ph: 416/243-1900
Fax: 416/243-2336

Wainbee, Limited
215 Brunswick Drive
Pointe Claire, P.Q. Canada H9R 4R7
Ph: 514/697-8810
Fax: 514/697-3070

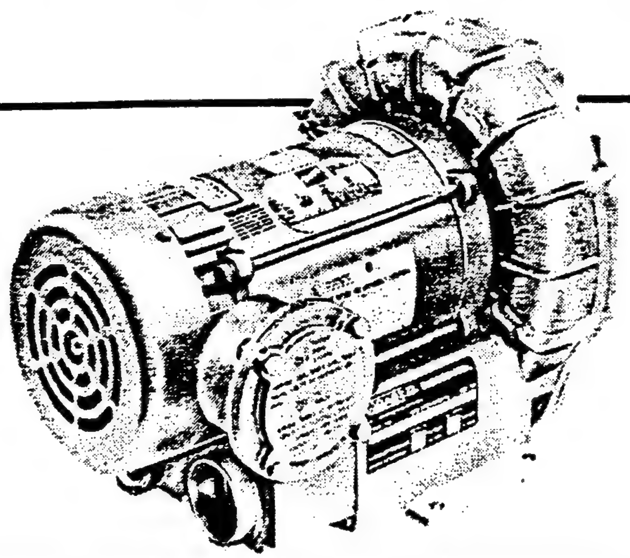
Gast Mfg. Co. Limited.
Halifax Rd, Cressex Estate
High Wycombe, Bucks HP12 3SN
Ph. 44 494 523571
Fax: 44 494 436588

Japan Machinery Co. Ltd.
Central PO Box 1451
Tokyo 100-91 Japan
Ph: 813/3573-5421
Fax: 813/3571-7865

Regenerative Blowers For Soil Remediation to 260 cfm

GAST

R4, R5, R6P Series



MODEL R4 SERIES
48" H_2O MAX. VAC., 88 CFM OPEN FLOW

MODEL R5 SERIES
60" H_2O MAX. VAC., 145 CFM OPEN FLOW

MODEL R6P SERIES
90" H_2O MAX. VAC., 260 CFM OPEN FLOW

PRODUCT FEATURES

- Explosion-proof motors UL (class 1, group D; class 2, groups F & G)
- Sealed air stream
- Rugged construction
- Low maintenance

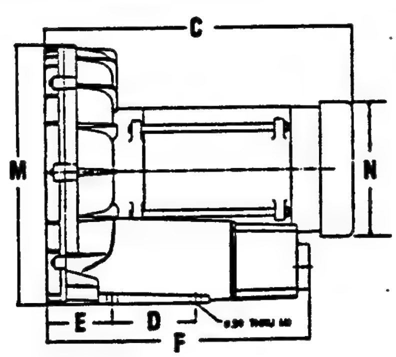
RECOMMENDED ACCESSORIES

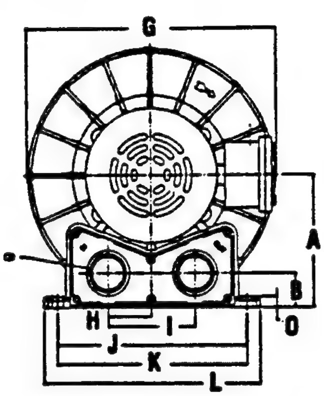
- Inlet filter AJ151G (Reducing filter plumbing from 2½" to 1½" is needed to accommodate filter on R4 and R5 models.)
- Relief valve AG258
- Vacuum gauge AE134

Product Dimensions Metric (mm) U.S. Imperial (inches)

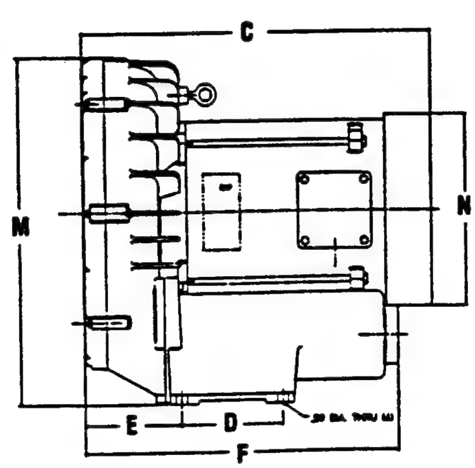
Model	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
R4110N-50	157	43	360	95	72	316	313	50	101	225	227	254	293	175	11
	6.18	1.68	14.16	3.75	2.85	12.44	12.31	1.98	3.96	8.86	8.93	10.00	11.73	6.88	.44
R4310P-50	157	43	360	95	72	316	313	50	101	225	227	254	293	175	11
	6.18	1.68	14.17	3.75	2.84	12.44	12.31	1.98	3.96	8.86	8.93	10.00	11.73	6.88	.44
R5325R-50	178	46	423	114	91	361	344	60	121	260	262	298	350	183	15
	7.00	1.82	16.66	4.50	3.58	14.22	13.56	2.38	4.75	10.25	10.31	11.75	13.78	7.19	.59
R6P355R-50	248	80	482	140	137	438	428	64	127	–	290	325	463	257	13
	9.77	3.15	18.98	5.51	5.39	17.25	16.87	2.50	5.00	–	11.42	12.80	18.21	10.12	.50

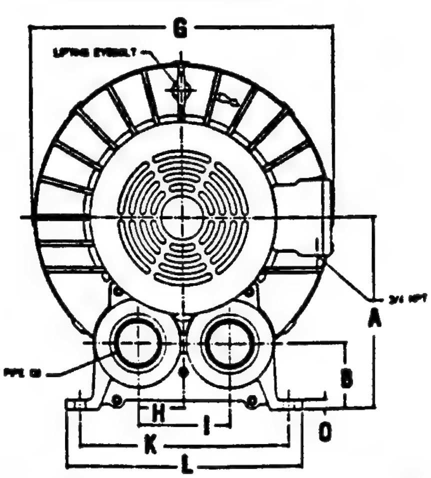
Model R4 Series
Model R5 Series



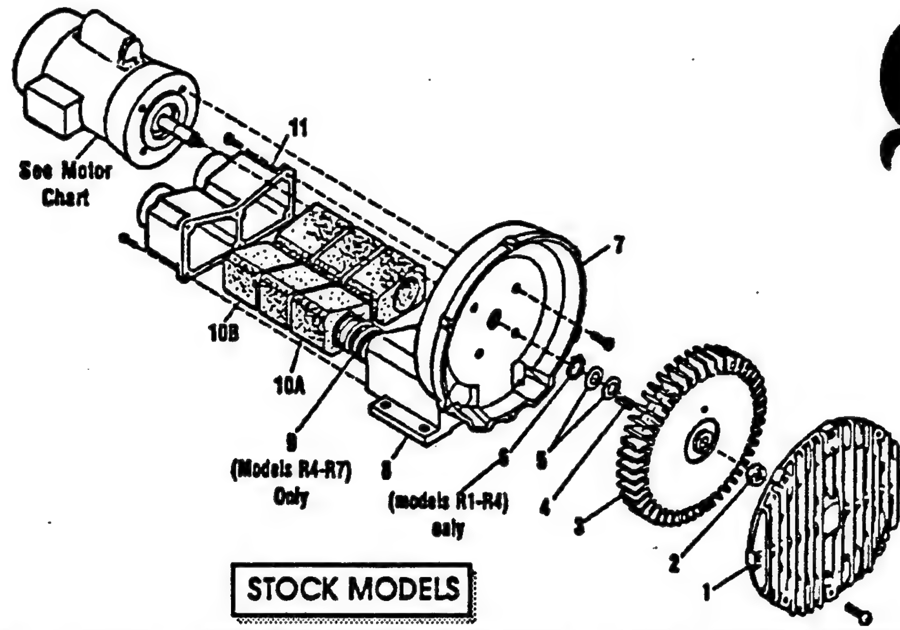


Model R6P Series





NOTE: These units with explosion-proof motors are designed specifically for qualified OEMs in the soil remediation industry. They are not intended to be applied for other uses without written acknowledgement from an authorized employee of Gast Manufacturing Corporation.



STOCK MODELS

Part Name	R1	R2	R3	R4	R5	R6	R6P	R6PP/R6PS	R7
#1 Cover	AJ101A	AJ101B	AJ101C	AJ101D	AJ101EQ	AJ101F	AJ101K	(2)AJ101KA	AJ101G
#2 Stopnut	BC187	BC187	BC181	BC181	BC181	BC181	BC181	(2)BC182	BC183
#3 Impeller	AJ102A	AJ102BQ	AJ102C	AJ102D	AJ102E	AJ102FR	AJ102K	(2)AJ102KA	AJ102GA
#4 Square Key	AH212C	AH212	AB136A	AB136D	AB136	AB136	AB136	(2)AB136	AC628
#5 Shim Spacer (s)	AJ132	AE686-3	AJ109	AJ109	AJ109	AJ116A	AJ116A	AJ116A	AJ110
#6 Retaining Ring	AJ145	AJ145	AJ149	AJ149					
#7 Housing	AJ103A	AJ103BQ	AJ103C	AJ103DR	AJ103E	AJ103F	AJ103K	AJ103KD	AJ103GA
#8 Muffler Box					AJ104E	AJ104F			
#9 Spring				AJ113DR	AJ113DQ	AJ113FQ	AJ113FQ		AJ113G
#10A Foam	(4)AJ112A	(4)AJ112B	(4)AJ112C	(4)AJ112DS	(4)AJ112ER	(6)AJ112F	(8)AJ112K		(8)AJ112GA
#10B Foam		(2)AJ112BQ	(2)AJ112CQ	(2)AJ112DR	(2)AJ112EQ				
#11 Muffler Extension/ Adapter Plate	AJ106H	AJ106BQ	AJ106CQ	AJ106DQ	AJ106EQ	AJ106FQ	AJ104K		AJ104GA
Shim Kit	K396	K396							K395

MOTOR CHART

REGENAIR MODEL NUMBER	MOTOR NUMBER	MOTOR SPECIFICATIONS 60 HZ VOLTS	50 HZ VOLTS	PHASE
R1102	J111X	115/208-230	110/220-240	1
R1102C	J112X	115		1
R2103	J311X	115/208-230	110/220	1
R2105	J411X	115/208-230	110/220	1
R2303A	J310	208-230/460	220/380-415	3
R2303F	J313	208-230	220	3
R3105-1/R3105-12	J411X	115/208-230	110/220-240	1
R3305A-1/R3305A-13	J410	208-230/460	220/380-415	3
R4110-2	J611AX	115/208-230	110/220-240	1
R4310A-2	J610	208-230/460	220/380-415	3
R5125-2	J811X	115/208-230		1
R5325A-2	J810X	208-230/460	220/380-415	3
R6125-2	J811X	115/208-230		1
R6325A-2	J810X	208-230/460	220/380-415	3
R6335A-2	J910X	208-230/460	220/380-415	3
R6150J-2	J1013	230		1
R6350A-2	J1010	208-230/460	220/380-415	3
R6P335A	J910X	208-230/460	220/380-415	3
R6P350A	J1010	208-230/460	220/380-415	3
R6P355A	J1110A	208-230/460	220/380-415	3
R7100A-2*	J1210B	208-230/460	220/380-415	3
R6PP/R6PS3110M	JD1100	208-230/460	220/380-415	3

* No lubrication needed at start up. Bearings lubricated at factory.

* Motor is equipped with alemite fitting. Clean tip of fitting and apply grease gun. Use 1 to 2 strokes of high quality ball bearing grease.

Consistency	*Type*	*Typical Grease*
Medium	Lithium	Shell Dolium R

Hours of service per year	*Suggested Relube Interval*
5,000	3 years
Continual Normal Application	1 year
Seasonal service motor idle for 6 months or more	1 year beginning of season
Continuous-high ambients, dirty or moist applications.	6 months

60 HZ FLOW DATA (CFM)

All performance figures relate to stock models. A few high pressure units may be available. Consult your local distributor.

Regenair Model Number	PRESSURE 0"H_2O	20"H_2O	40"H_2O	60"H_2O	80"H_2O	100"H_2O	Maximum Pressure "H_2O"*
R1	26	14					28
R2	42	26					38
R3105-1	52	38	14				42
R3105-12	52	36	23				55
R3305A-13	52	36	23				55
R4	90	70	50				52
R5	145	130	100				65
R6125-2	200	180					35
R6325A-2	200	180	152				40
R6335A-2	205	175	155	135			70
R6350A-2	200	180	150	130	110	80	105
R6P335A	290	250					30
R6P350A	300	260	230	200			60
R6P355A	300	260	230	200	160		90
R7100A-2	420	380	340	310	280	230	115
R6PP311OM	485	452	420	380	330		95
R6PS311OM	265	258	252	244	236	226	170

Regenair Model Number	VACUUM 0"H_2O	20"H_2O	40"H_2O	60"H_2O	80"H_2O	Maximum Vacuum "H_2O"*
R1	25	14				26
R2	40	22				34
R3105-1	50	34	9			40
R3105-12	51	34	20			50
R3305A-13	51	34	20			50
R4	82	62	39			48
R5	140	115	90	50		60
R6125-2	190	155	125			45
R6325A-2	190	155	125			45
R6335A-2	190	150	125	100		75
R6350A-2	190	180	150	100	70	90
R6P335A	270	230				37
R6P350A	280	240	210	170		70
R6P355A	280	240	210	170	100	86
R7100A-2	410	350	300	250	170	90
R6PP311OM	470	425	375	320	220	80
R6PS311OM	240	225	210	195	175	130

***This number indicates the maximum static pressure differential recommended (with cooling air still flowing through unit). In general, units 1hp or less can be dead headed. Check with local representative or distributor to verify which models apply.**

Operation of the blower above the recommended maximum duty will cause premature failure due to the build up of heat damaging the components.

Performance data was determined under the following conditions:

1) Unit in a temperature stable condition.
2) Test conditions: Inlet air density at 0.075lbs. per cubic foot. (20°C(68°F), 29.92 in. Hg(14.7PSIA)).
3) Normal performance variations on the resistance curve within +/- 10% of supplied data can be expected.
4) Specifications subject to change without notice.
5) All performance at 60Hz operation.

70-6100
F2-205/8/92
AK811 Rev. E

Post Office Box 97
Benton Harbor, MI. 49023-0097
Ph: 616/926-6171
Fax: 616/925-8288

INSTALLATION AND OPERATING INSTRUCTIONS FOR GAST HAZARDOUS DUTY REGENAIR BLOWERS

This instruction applies to the following models ONLY: R3105N-50, R4110N-50, R4310P-50, R4P115N-50, R5125Q-50, R5325R-50, R6130Q-50, R6P155Q-50, R6350R-50, R6P355R-50 and R7100R-50.

Gast Authorized Service Facilities are Located in the locations listed below

Gast Manufacturing Corporation
505 Washington Avenue
Carlstadt, N. J. 07072
Ph: 201/933-8484
Fax: 201/933-5545

Gast Manufacturing Corporation
2550 Meadowbrook Road
Benton Harbor, MI. 49022
Ph: 616/926-6171
Fax: 616/925-8288

Brenner Fiedler & Associates
13824 Bentley Place
Cerritos, CA. 90701
Ph: 213/404-2721
Ph: 800/843-5558
Fax: 213/404-7975

Wainbee Limited
215 Brunswick Blvd.
Pointe Claire, Quebec
Canada H9R 4R7
Ph: 514/697-8810
Fax: 514/-697-3070

Wainbee Limited
5789 Coopers Ave.
Mississauga, Ontario
Canada L4Z 3S6
Ph: 416/243-1900
Fax: 416/243-2336

Japan Machinery
Central PO Box 1451
Toyko 100-91, Japan
Ph: 813 3573-5421
Fax: 813 3571-7896

Gast Manufacturing Co. Ltd.
Halifax Road, Cressex Estate
High Wycombe, Bucks HP12 3SN
England
Ph: 44 494 523571
Fax: 44 494 436588

Safety

⚠ This is the safety alert symbol. When you see this symbol, personal injury is possible. The degree of injury is shown by the following signal words:

⚠ DANGER: Severe injury or death will occur if hazard is ignored.

⚠ WARNING: Severe injury or death can occur if hazard is ignored.

⚠ CAUTION: Minor injury or property damage can occur of hazard is ignored.

Review the following information carefully before operating.

General Information

⚠ DANGER: Do not pump flammable or explosive gases or operate in an atmosphere containing them. Ambient temperature for normal operation should not exceed 40 degrees C (105 degrees F). For higher ambient operation, consult the factory. Blower performance is reduced by the lower atmospheric pressure of high altitudes. If it applies to this unit, consult a Gast distributor or the factory for details.

Installation

⚠ WARNING: Electric Shock can result from bad wiring. Wiring must conform to all required safety codes and be installed by a qualified person.

Grounding is required.

The Gast Regenair blower can be installed in any position. The flow of cooling air over the blower and motor must not be blocked.

PLUMBING - The threaded pipe ports are designed as connection ports only and will not support the plumbing. Be sure to use the same or larger size pipe and fittings to prevent air flow restriction and over-heating of the blower. When installing plumbing, be sure to use a small amount of pipe thread lubricant. This protects the threads in the aluminum blower housing. Dirt and chips, often found in new plumbing, should not be allowed to enter the blower.

NOISE - To reduce noise and vibration, the unit should be mounted on a solid surface that will not increase sound. The use of shock mounts or vibration isolation material is recommended. If needed, inlet or discharge noise can be reduced by attaching muffler assemblies (see accessories).

ROTATION - The Gast Regenair blower should only rotate clockwise as viewed from the electric motor side. This is marked with an arrow in the casting. Proper rotation can be confirmed by checking air flow at the IN and OUT ports. On blowers powered by a three phase motor, rotation is reversed by changing any two of the three power wires.

Operation

⚠ WARNING: Solid or liquid material exiting the blower or piping can cause eye damage or skin cuts. Keep away from air stream.

⚠ CAUTION: Attach blower to solid surface before starting. Prevent injury or damage from unit movement.

Air containing solid particles or liquid must pass through a filter before entering the blower (see accessories list for filter suggestions). Blowers must have mufflers, filters, other accessories and all piping attached before starting. Any foreign material passing through the blower may cause internal damage.

⚠ CAUTION: Outlet piping can burn skin. Guard or limit access.

Mark "CAUTION Hot surface. Can cause burns."

Air temperature increases when passing through the blower. When run at duties above 50 in. H_2O, metal pipe may be required for hot exhaust air.

The blower must not be operated above the limits for continuous duty. "Standard" R1, R2, R3 and R4 can operate continuously with not air flowing through the blower. Other units can only be run at the rating shown on the model number label. Do *not* close off inlet (for vacuum) or exhaust (for pressure) to reduce extra air flow. This could cause added heat and motor load.

ACCESSORIES - Gast pressure gauges AJ496 or AE133 and vacuum gauges AJ497 or AE134 show blower duty. The Gast pressure/vacuum relief valve, AG258, will limit the operating duty by admitting or relieving air. It also allows full flow through the blower when the relief valve closes.

Servicing

⚠ **WARNING: Disconnect electric power before servicing. Be sure rotating parts have stopped. Electric shock or severe cuts can result. Inlet and exhaust filters need occasional cleaning or replacement of the elements. Failure to do so will result in more pressure drop, reduced air flow and hotter operation. The outside of the unit requires cleaning of dust and dirt. The inside of the blower also may need cleaning to remove material coating the impeller and housing. If not done, the buildup can cause vibration, hotter operation and reduced flow. Noise absorbing foam in the mufflers may need replacement.**

KEEP THIS INFORMATION WITH THE BLOWER. REFER TO IT FOR SAFE INSTALLATION, OPERATION OR SERVICE.

TROUBLESHOOTING

Symptom	*Possible Diagnosis*	*Possible Remedy*
Excess Vibration	Impeller damaged by foreign material Impeller contaminated by foreign material	Replace impeller Clean impeller, install adequate filtration.
Abnormal sound	Motor bearing failed Impeller rubbing against cover or housing	Replace bearings Repair Blower, check clearances.
Increase in sound	Foreign material can coat or destroy muffler foam.	Replace foam muffler elements, trap or filter foreign material.
Blown fuse	Electrical wiring problem	Have qualified person check fuse capacity and wiring.
Unit very hot	Running at too high a pressure or vacuum	Install a relief valve

OPERATING AND MAINTENANCE INSTRUCTIONS

SAFETY

This is the safety alert symbol. When you see this symbol personal injury is possible. The degree of injury is shown by the following signal words:
DANGER Severe injury or death will occur if hazard is ignored.
WARNING Severe injury or death can occur if hazard is ignored.
⚠ CAUTION Minor injury or property damage can occur if hazard is ignored.

Review the following information carefully before operating.

GENERAL INFORMATION

This instruction applies to the following models ONLY: R3105N-50, R4110N-50, R4310P-50, R4P115N-50, R5125Q-50, R5325R-50, R6130Q-50, R6P155Q-50, R6350R-50, R6P355R-50 and R7100R-50. These blowers are intended for use in Soil Vapor Extraction Systems. The blowers are sealed at the factory for very low leakage. They are powered with a U.L. listed electric motor Class 1 Div. 1 Group D motors for Hazardous Duty locations. Ambient temperature for normal full load operation should not exceed 40° C (105° F). For higher ambient operation, contact the factory.

Gast Manufacturing Corporation may offer general application guidance: however, suitability of the particular blower and/or accessories is ultimately the responsibility of the user, not the manufacturer of the blower.

INSTALLATION

DANGER Models R5325R-50, R6130Q-50, R6350R-50, R5125Q-50, R6P155Q-50, R6P355R-50 AND R7100R-50 use Pilot Duty Thermal Overload Protection. Connecting this protection to the proper control circuitry is mandated by UL674 and NEC501. Failure to do so could/ may result in a EXPLOSION. See pages 3 and 4 for recommended wiring schematic for these models.

WARNING Electric shock can result from bad wiring. A qualified person must install all wiring, conforming to all required safety codes. Grounding is necessary.

⚠ *WARNING This blower is intended for use on soil vapor extraction equipment. Any other use must be approved in writing by Gast Manufacturing. Corp.* Install this blower in any mounting position. Do not block the flow of cooling air over the blower and motor.
PLUMBING - Use the threaded pipe ports for connection only. They will not support the plumbing. Be sure to use the same or larger size pipe to prevent air flow restriction and overheating of the blower. When installing fittings, be sure to use pipe thread sealant. This protects the threads in the blower housing and prevents leakage. Dirt and chips are often found in new plumbing. Do not allow them to enter the blower.

NOISE - Mount the unit on a solid surface that will not increase the sound. This will reduce noise and vibration. We suggest the use of shock mounts or vibration isolation material for mounting.

ROTATION - The Gast Regenair Blower should only rotate clockwise as viewed from the electric motor side. The casting has an arrow showing the correct direction. Confirm the proper rotation by checking air flow at the IN and OUT ports. If needed reverse rotation of three phase motors by changing the position of any two of the power line wires.

OPERATION

⚠ *WARNING Solid or liquid material exiting the blower or piping can cause eye damage or skin cuts. Keep away from air stream.*

⚠ *WARNING - Gast Manufacturing Corporation will not knowingly specify, design or build any blower for installation in a hazardous, combustible or explosive location without a motor conforming to the proper NEMA or U. L. standards.* Blowers with standard TEFC motors should never be utilized for soil vapor extraction applications or where local state and/or Federal codes specify the use of explosion-proof motors (as defined by the National Electric Code, Articles 100,500 c1990).

⚠ *CAUTION Attach blower to solid surface before starting to prevent injury or damage from unit movement.* Air containing solid particles or liquid must pass through a filter before entering the blower. Blowers must have filters, other accessories and all piping attached before starting. Any foreign material passing through the blower may cause internal damage to the blower.

⚠ *CAUTION Outlet piping can burn skin. Guard or limit access. Mark "CAUTION Hot Surface. Can Cause Burns".* Air temperature increases when passing through the blower. When run at duties above 50 in. H_2O, metal pipe may be required for hot exhaust air. The blower must not be operated above the limits for continuous duty. Only models R3105N-50, R4110N-50 and R4310P-50 can be operated continuously with no air flowing through the blower. Other units can only be run at the rating shown on the model number label. Do not Close off inlet (for vacuum) to reduce extra air flow. This will cause added heat and motor load. Blower exhaust air in excess of 230°F indicates operation in excess of rating which can cause the blower to fail.

ACCESSORIES ...Gast pressure gauge AJ496 and vacuum gauges AJ497 or AE134 show blower duty. The Gast pressure/vacuum relief valve, AG258, will limit the operating duty by admitting or relieving air. It also allows full flow through the blower when the relief valve closes.

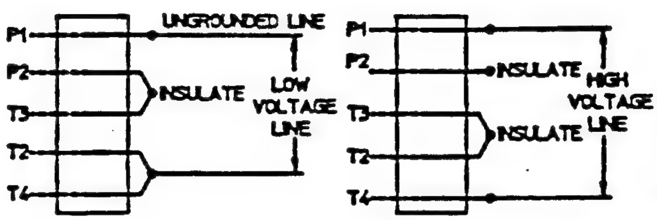
SERVICING

⚠ WARNING *To retain their sealed construction they should be serviced by Gast authorized service centers ONLY.* These models are sealed at the factory for very low leakage.

⚠ WARNING *Turn off electric power before removing blower from service. Be sure rotating parts have stopped. Electric shock or severe cuts can result.* Inlet and exhaust filters attached to the blower may need cleaning or replacement of the elements. Failure to do so will result in more pressure drop, reduced air flow and hotter operation of the blower. The outside of the unit requires cleaning of dust and dirt. The inside of the blower also may need cleaning to remove foreign material coating the impeller and housing. This should be done at a Gast Authorized Service Center. This buildup can cause vibration, failure of the motor to operate or reduced flow.

KEEP THIS INFORMATION WITH THIS BLOWER. REFER TO IT FOR SAFE INSTALLATION, OPERATION OR SERVICE.

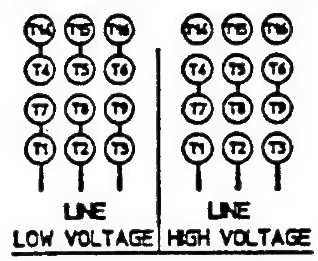
MOTOR WIRING DIAGRAM FOR R4110N-50 & R3105N-50



>>* WARNING
THIS MOTOR IS THERMALLY PROTECTED AND WILL AUTOMATICALLY RESTART WHEN PROTECTOR RESETS. ALWAYS DISCONNECT POWER SUPPLY BEFORE SERVICING.

MOTORS WIRING DIAGRAM FOR R4310P-50

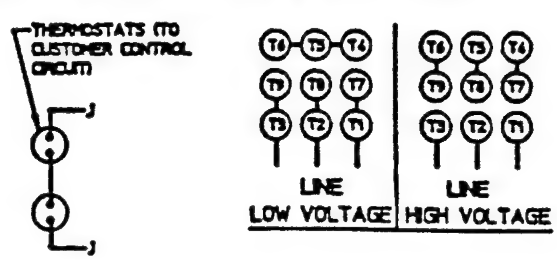
TO REVERSE ROTATION, INTERCHANGE THE EXTERNAL CONNECTIONS TO ANY TWO LEADS.



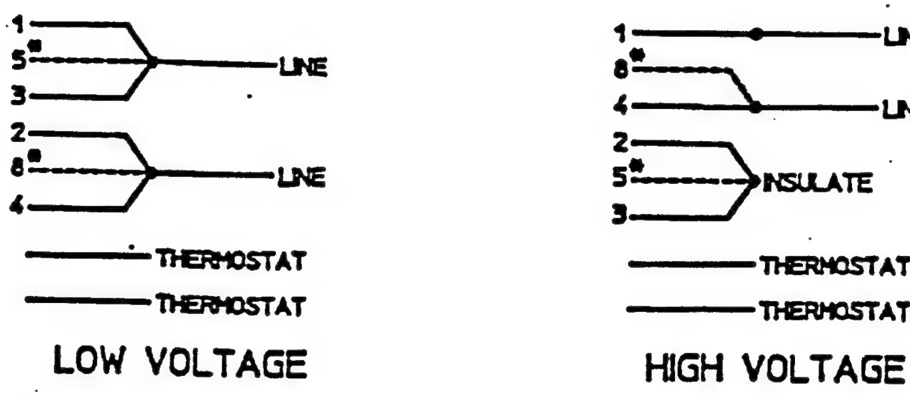
>>* WARNING
THIS MOTOR IS THERMALLY PROTECTED AND WILL AUTOMATICALLY RESTART WHEN PROTECTOR RESETS. ALWAYS DISCONNECT POWER SUPPLY BEFORE SERVICING.

MOTORS WIRING DIAGRAM FOR R5325R-50, R6350R-50, R6P355R-50, & R7100R-50

TO REVERSE ROTATION, INTERCHANGE THE EXTERNAL CONNECTIONS TO ANY TWO LEADS.



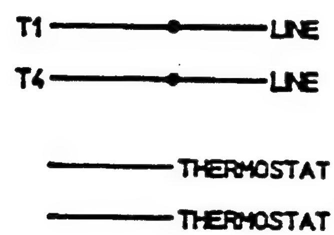
MOTOR WIRING DIAGRAM FOR R5125Q-50 & R4P115N-50



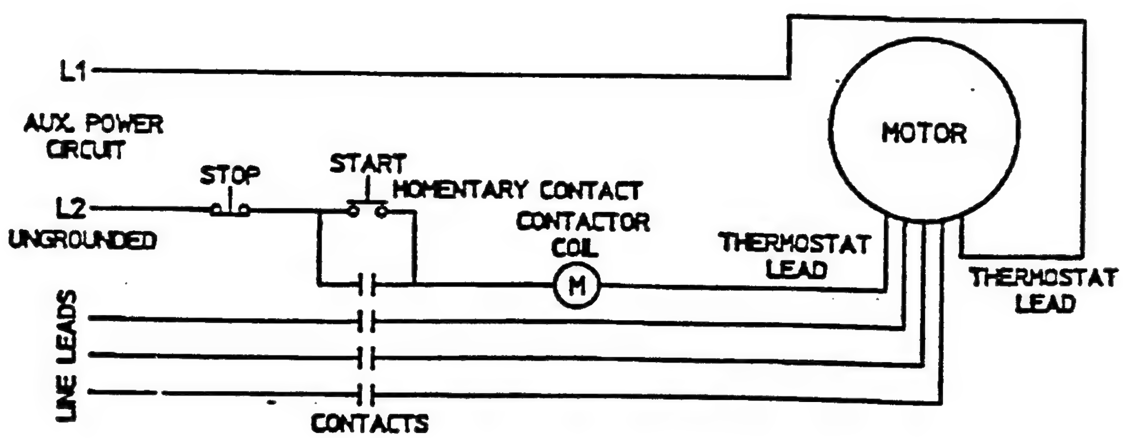
* R5125Q-50 BLOWERS PRODUCED AFTER SEPTEMBER 1992 (SER. NO. 0992)
DO NOT HAVE MOTOR LEADS 5 & 8.

MOTOR WIRING DIAGRAM FOR R6130Q-50 & R6P155Q-50

CONNECT THERMOSTAT
TO MOTOR PROTECTION
CIRCUIT



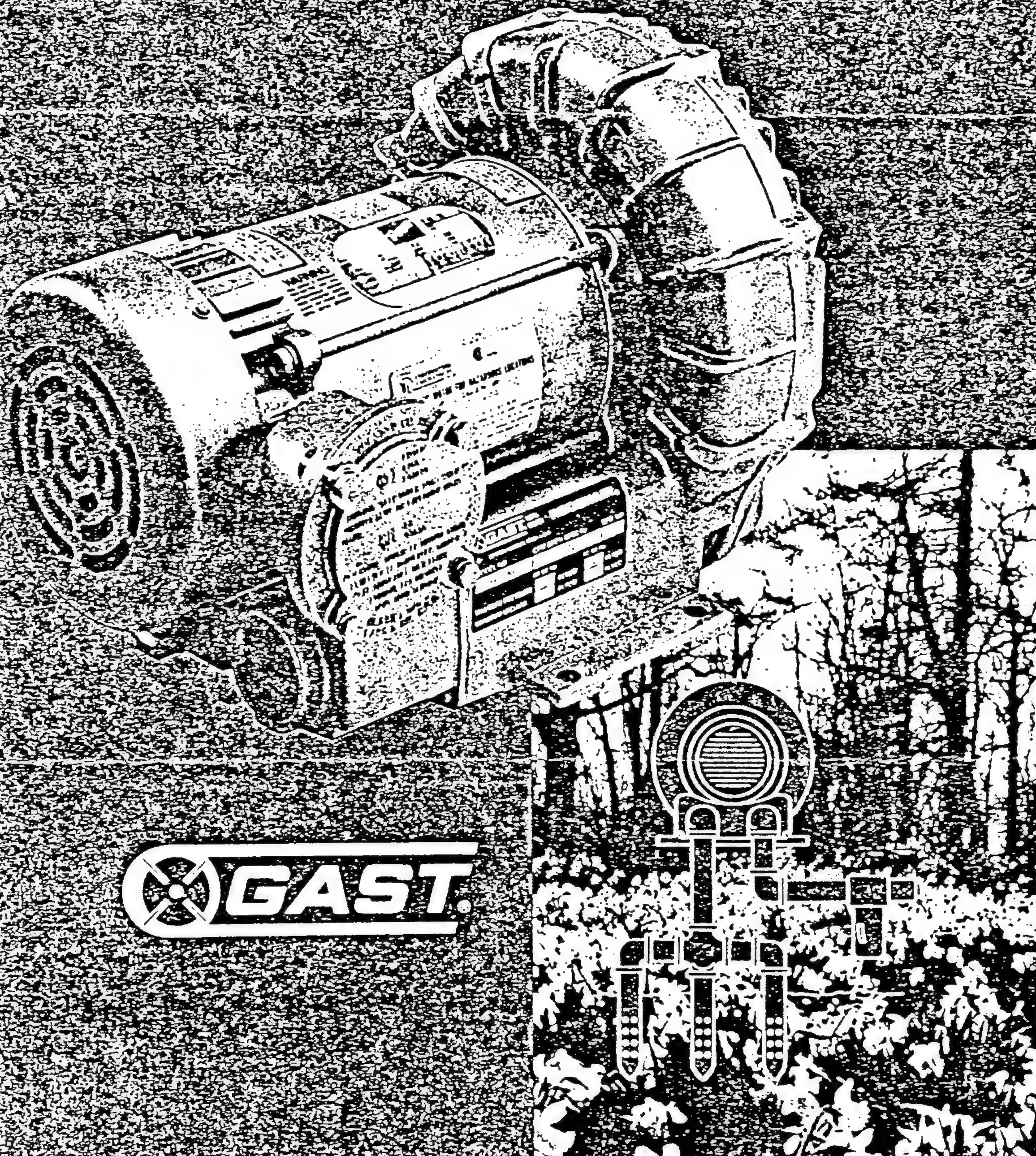
CONNECTION FOR THERMOSTAT MOTOR PROTECTION



TERMOSTATS TO BE CONNECTED IN SERIES WITH
CONTROL AS SHOWN. MOTOR FURNISHED WITH
AUTOMATIC THERMOSTATS RATED A.C. 115-600V. 720VA

Blowers for

SOIL VAPOR EXTRACTION



GAST

Your Warranty

REGARDLESS OF CAUSE, if a product you buy from this catalog does not work right, Gast will repair or replace it once, at no charge, for up to one year from the date of shipment from the factory.

In the course of repair or replacement, Gast may send you written recommendations on how to prevent a problem from happening again. Gast reserves the right to withdraw this warranty if you do not follow these recommendations. Customer is responsible for freight charges both to and from Gast in all cases.

THIS WARRANTY DOES NOT APPLY TO ELECTRIC MOTORS, ELECTRICAL CONTROLS AND GASOLINE ENGINES, WHICH GAST OBTAINS FROM OTHER MANUFACTURERS. A MOTOR OR ENGINE CARRIES ONLY THE WARRANTY OF THE COMPANY THAT MAKES IT. THIS WARRANTY IS EXCLUSIVE AND IS IN LIEU OF ALL OTHER WARRANTIES, WHETHER WRITTEN, ORAL OR IMPLIED, INCLUDING THE WARRANTY OF MERCHANTABILITY AND OF FITNESS FOR ANY PARTICULAR PURPOSE. GAST'S LIABILITY IS IN ALL CASES LIMITED TO THE REPLACEMENT PRICE OF ITS PRODUCT. GAST SHALL NOT BE LIABLE FOR ANY OTHER DAMAGES, WHETHER CONDSEQUENTIAL, INDIRECT, OR INCIDENTAL, ARISING FROM THE SALE OR USE OF ITS PRODUCTS.

Gast's sales personnel may modify this warranty, but only by signing a specific, written description of any modifications.

Gast Manufacturing Corporation

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Fax: 616/925-8288

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Eastern Sales Office
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Carlstadt, NJ 07072
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Wood Dale, IL 60191
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Telex 83488

GAST®

Printed on recycled paper

F2-11 (3-93)

GAST REGENAIR® Blowers

FOR SOIL VAPOR

designed to supply up to 420 cfm (714m 3/hr), 7 in Hg/224 mbar (90" H_2O) or 4 psi/249 mbar (100" H_2O)

The Gast reputation for quality and customer satisfaction is renowned throughout the world. Since 1921 we have been supplying air moving products that have set the industry standard of excellence. Our regenerative blowers for soil vapor extraction are no exception. Designed to extract vapors from contaminated soils, these models are used in conjunction with site-supplied special filters which clean the contaminants before venting them to the atmosphere. Since this process can take months or even years, Gast environmental blowers are a perfect solution; the only wearing part is the bearing, which is rated for up to 25,000 hours of service. Also, each of our motor-mounted models comes with a Class 1 Group D explosion-proof motor as a standard feature. Combining this quality with the strongest warranty in the business and a vast national and international distribution network providing product and technical support, we think you'll find our special Gast Regenair® blowers to be the right choice for your soil vapor extraction needs.

MODEL R4 SERIES
48" H_2O MAX. VAC., 51" H_2O MAX. PRESSURE
92 CFM OPEN FLOW

MODEL R5 SERIES
60" H_2O MAX. VAC., 65" H_2O MAX. PRESSURE
160 CFM OPEN FLOW

MODEL R6 SERIES
70" H_2O MAX. VAC., 75" H_2O MAX. PRESSURE
215 CFM OPEN FLOW

MODEL R6P SERIES
85" H_2O MAX. VAC., 100" H_2O MAX. PRESSURE
280 CFM OPEN FLOW

MODEL R7 SERIES
90" H_2O MAX. VAC., 90" H_2O MAX. PRESSURE
420 CFM OPEN FLOW

PRODUCT FEATURES
- Explosion-proof motors UL (class 1, group D)
- Sealed air stream
- Rugged construction
- Low maintenance

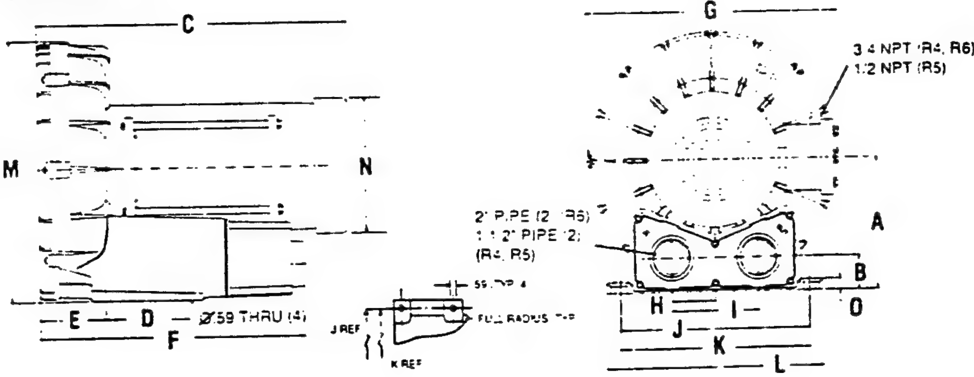
Product Dimensions

Metric (mm)
U.S. Imperial (inches)

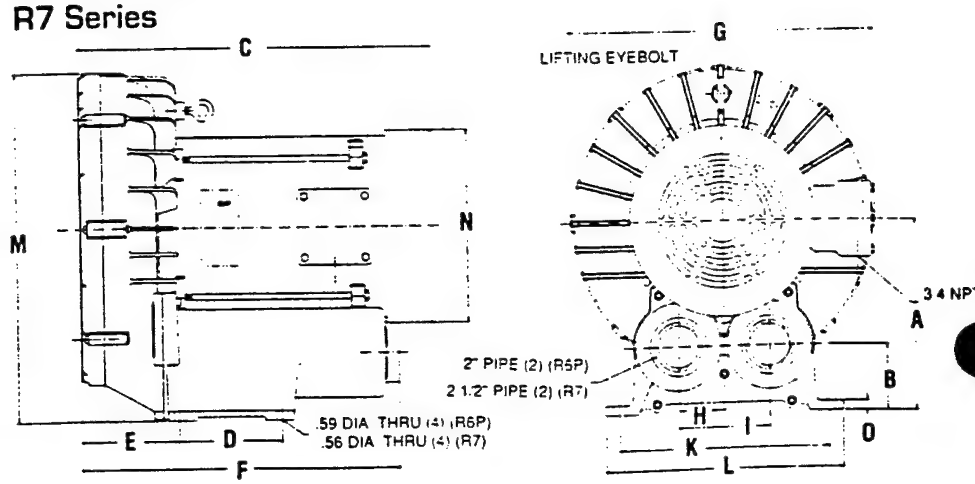
Model	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
R4110N-50	157	43	389	95	72	316	313	50	101	225	227	254	293	175	11
	6.18	1.68	15.30	3.75	2.85	12.44	12.31	1.98	3.96	8.86	8.93	10.00	11.73	6.88	.44
R4310P-50	157	43	356	95	72	316	313	50	101	225	227	254	293	175	11
	6.18	1.68	14.03	3.75	2.84	12.44	12.31	1.98	3.96	8.86	8.93	10.00	11.73	6.88	.44
R5125Q-50	178	46	445	114	91	361	344	60	121	260	262	298	350	173	15
	7.00	1.82	17.50	4.50	3.58	14.22	13.56	2.38	4.75	10.25	10.31	11.75	13.78	6.81	.59
R5325R-50	178	46	423	114	91	361	344	60	121	260	262	298	350	183	15
	7.00	1.82	16.66	4.50	3.58	14.22	13.56	2.38	4.75	10.25	10.31	11.75	13.78	7.19	.59
R6130Q-50	197	49	511	140	98	404	389	62	125	289	290	329	391	217	13
	7.75	1.94	20.13	5.50	3.85	15.89	15.30	2.46	4.92	11.38	11.42	12.96	15.38	8.56	.52
R6P155OQ-50	248	80	602	140	137	438	428	64	127	-	290	325	463	257	13
	9.77	3.15	23.7	5.51	5.39	17.25	16.87	2.50	5.00	-	11.42	12.80	18.21	10.12	.50
R6P355R-50	248	80	554	140	137	438	428	64	127	-	290	325	463	257	13
	9.77	3.15	21.80	5.51	5.39	17.25	16.87	2.50	5.00	-	11.42	12.80	18.21	10.12	.50
R7100R-50	274	92	577	216	212	545	457	100	200	-	375	410	509	257	14
	10.79	3.64	22.72	8.50	8.33	21.46	18.00	3.94	7.88	-	14.76	16.14	20.02	10.12	.56

Notice: Specifications subject to change without notice.

R4 Series
R5 Series
R6 Series



R6P Series
R7 Series



More models may be available – please consult factory

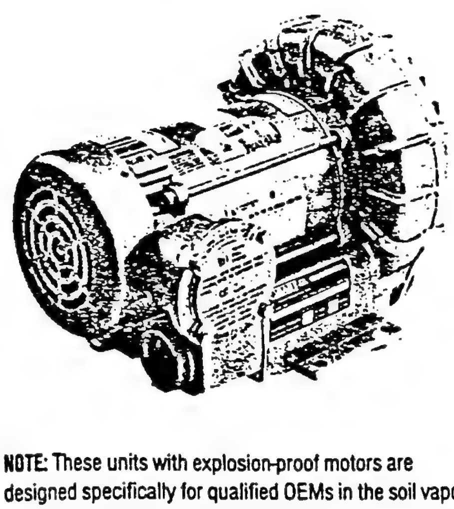
EXTRACTION...

Product Specifications

Model Number	Hz	Motor Specs	Full Load Amps	HP	RPM	Max Vac "H_2O	Max Vac mbar	Max Pressure "H_2O	Max Pressure mbar	Max Flow cfm	Max Flow m³h	Net. W lbs.
R4110N-50	50	110/220-240-50-1*	9.2/5.2-4.6	0.6	2850	35	87	38	95	74	126	60
	60	115/208-230-60-1*	11.4/6.2-5.6	1.0	3450	48	120	51	127	92	156	
R4310P-50	50	220/380-50-3*	3.2/1.6	0.6	2850	35	87	38	95	74	126	58
	60	208-230/460-60-3*	3.4-3.3/1.65	1.0	3450	48	120	51	127	92	156	
R5125Q-50	60	115/230-60-1	25/12.5	2.0	3450	60	149	55	137	160	272	77
R5325R-50	50	190-220/380-415-50-3	5.0-4.4/2.5-2.6	1.5	2850	47	117	50	125	133	226	75
	60	208-230/460-60-3	6.0-5.6/2.8	2.0	3450	60	149	65	162	160	272	
R6130Q-50	50	220-240-50-1	14.7-13.5	2.5	2850	65	162	75	187	182	309	129
	60	230-60-1	16.3	3.0	3450	70	174	60	149	215	365	
R6P155Q-50	50	220-240-50-1	20.8-19.1	4.0	2850	65	162	80	199	235	399	243
	60	230-60-1	29.9	5.5	3450	85	212	95	237	280	476	
R6P355R-50	50	190-220/380-415-50-3	14.9-11/7.45-5.8	4.5	2850	65	162	80	199	232	394	233
	60	208-230/460-60-3	20-18/9	6.0	3450	85	212	100	249	280	476	
R7100R-50	50	190-220/380-415-50-3	20.8-18.9/10.4-9.5	8	2850	72	179	80	199	350	595	297
	60	208-230/460-60-3	26.5-24/12	10	3450	90	224	90	224	420	714	

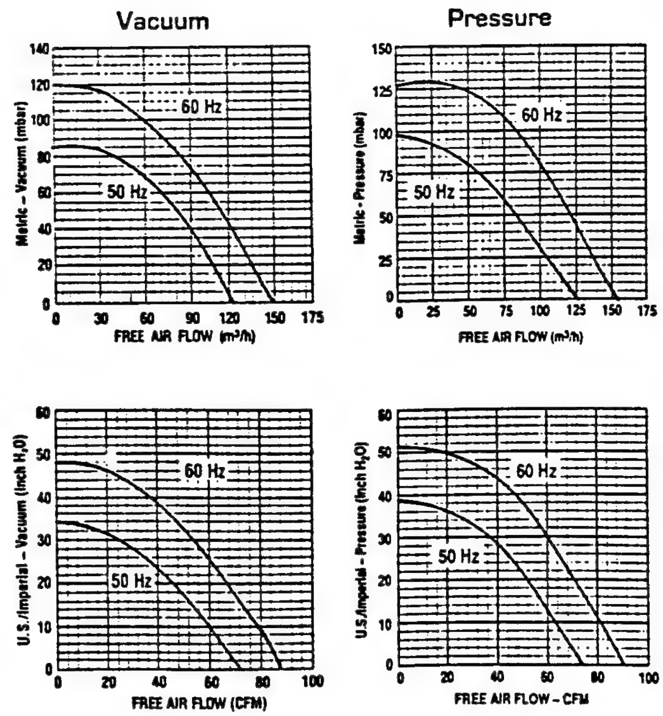
*Models have automatic reset thermal protection.

Product Performance
(Metric/U.S. Imperial)



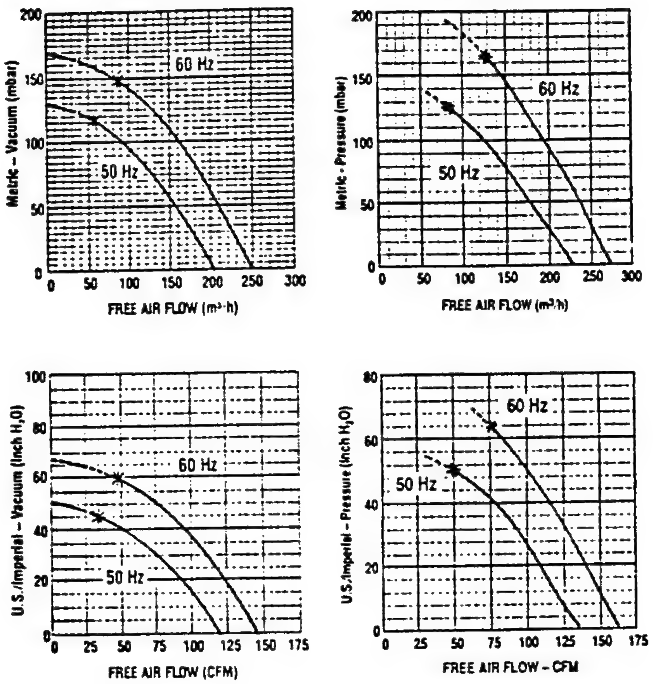
NOTE: These units with explosion-proof motors are designed specifically for qualified OEMs in the soil vapor extraction industry. They are not intended to be applied for other uses without written acknowledgment from an authorized employee of Gast Manufacturing Corporation.

Model R4 Series



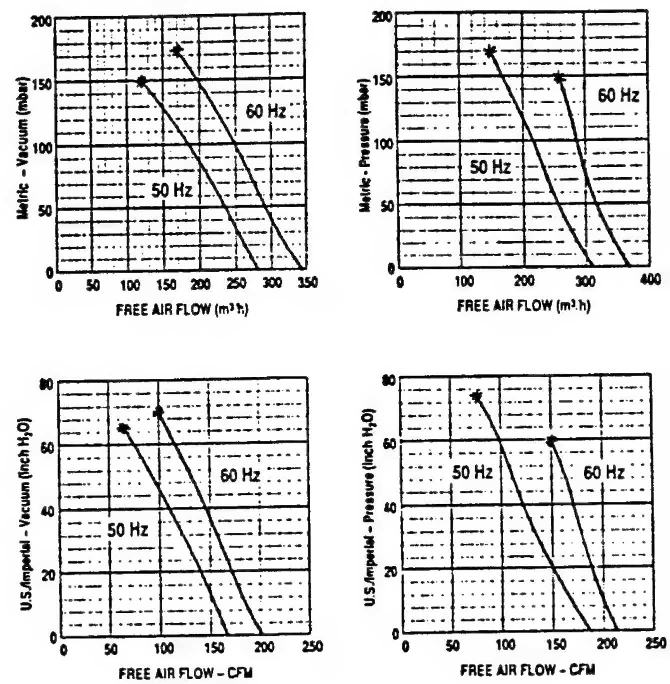
Model R5 Series

Vacuum / Pressure



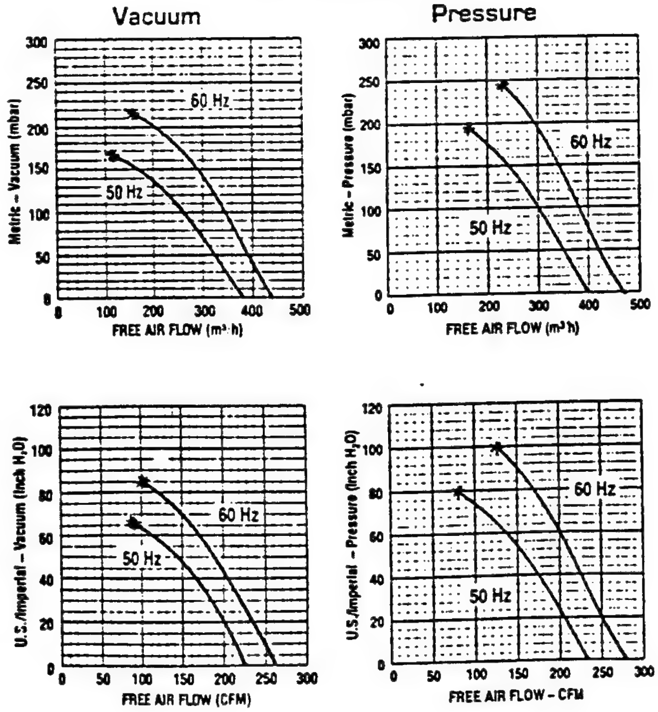
Model R6 Series

Vacuum / Pressure



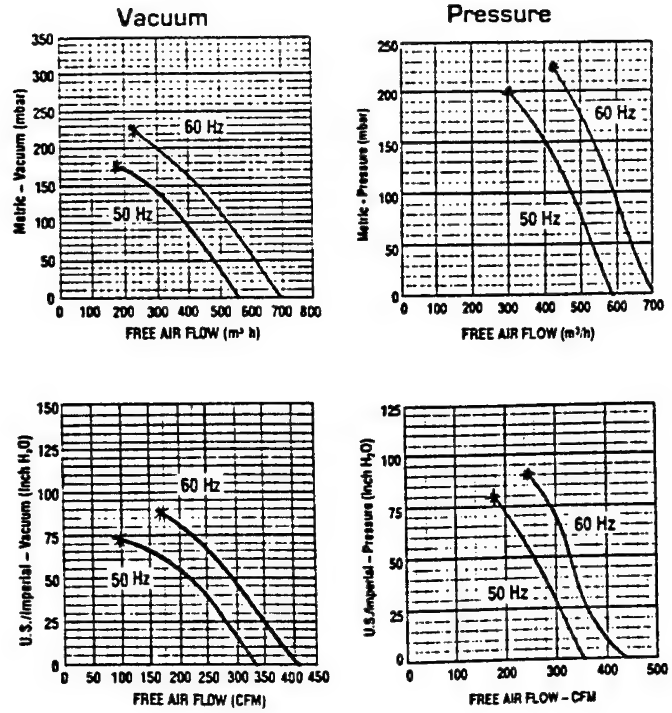
Model R6P Series

Vacuum / Pressure



Model R7 Series

Vacuum / Pressure

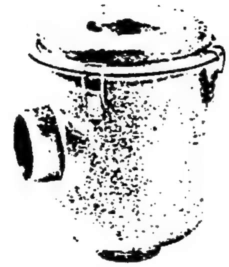


** Recommended maximum duty. ------- Intermittent duty only.*

Blower Accessories

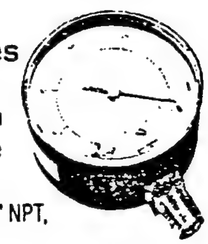
In-line Filters

The impeller of a blower passes very close to the housing. It is always wise to have an inlet or in-line filter to ensure troublefree life.



Model No.	R4	R5	R6,R6P	R7
Part No.	AJ151D	AJ151E	AJ151G	AJ151H
Replacement Element	AJ135E	AJ135F	AJ135G	AJ135C
Micron	10	10	10	10

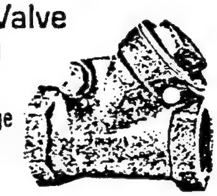
Vacuum and Pressure Gauges



To monitor the system performance so as not to exceed maximum duties. Using two (one on each side of the filter) is a great way to know when the filter needs servicing.

- Vacuum Gauge, Part #AJ497, 2 5/8" Dia., 1/4" NPT, 0-60 in. H_2O and 0-150 mbar
- Vacuum Gauge, Part #AE134, 2 5/8" Dia., 1/4" NPT, 0-160 in. H_2O and 0-400 mbar
- Pressure Gauge, Part #AJ496, 2 5/8" Dia., 1/4" NPT, 0-60 in. H_2O and 0-150 mbar
- Pressure Gauge, Part #AE133, 2 5/8" Dia., 1/4" NPT, 0-160 in. H_2O and 0-400 mbar
- Pressure Gauge, Part #AE133A, 2 5/8" Dia., 1/4" NPT, 0-200 in. H_2O

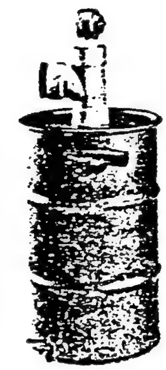
Horizontal Swing Type Check Valve



Designed to prevent back-wash of fluids that would enter the blower. Also prevents air back-streaming if needed. They can be mounted with their discharge either vertical or horizontal. Valve will open with 3" of water pressure.

Model No.	R4,R5	R6,R6P	R7
Part No.	AH326D	AH326F	AH326G
	1 1/2" NPT	2" NPT	2 1/2" NPT

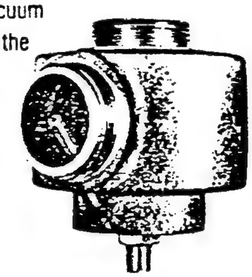
Moisture Separator



The purpose of the moisture separator is to remove liquids from the gas stream in a soil vapor extraction process. This helps protect the blower from corrosion and a build up of mineral deposits.

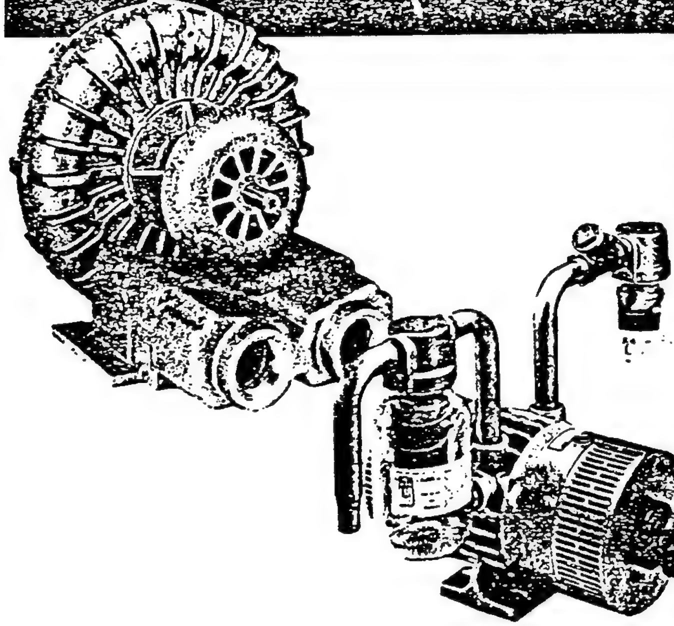
MODEL	LIQUID CAPACITY GALLONS	USED ON
RMS160	10	R4, R4P, R5
RMS200	19	R4, R4P, R5, R6
RMS300	19	R5, R6, R6P
RMS400	40	R6P, R7

Relief Valve



By setting a relief valve at a given pressure/vacuum you can be assured that no harm will come to the blower or products in your application from excessive duties.

- Pressure/Vacuum Relief Valve, 1 1/2" NPT, Adjustable 30 - 170 in. H_2O, 200 cfm max. Part #AG258

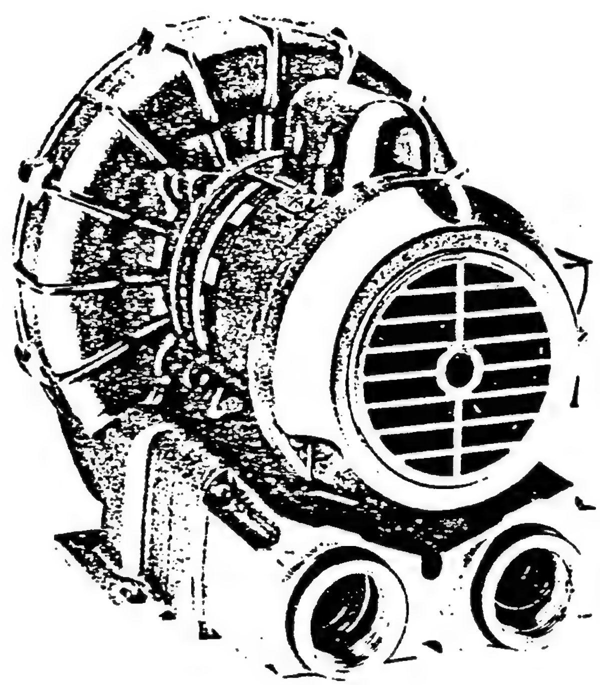


Gast also offers other models that are ideal for soil sparging. Our separate drive blowers are available in 4 sizes to 15 hp, pressures to 170" H_2O (6 psi). Rotary vane compressors are available in motor mounted or separate drive styles up to 5 hp, pressures to 20 psi.

Oilless Regenerative Blowers, Motor Mounted to 92 cfm

GAST

REGENAIR® R4 Series



MODEL R4110-2

52" H_2O MAX. PRESSURE, 92 CFM OPEN FLOW

PRODUCT FEATURES

- Oilless operation
- TEFC motor mounted
- Can be mounted in any plane
- Rugged construction/low maintenance
- Can be operated blanked-off

COMMON MOTOR OPTIONS

- 115/208-230V, 60 Hz; 110/220-240V, 50 Hz, single phase
- 208-230/460V, 60 Hz; 190-230/380-415V, 50 Hz, three phase
- 575V, 60 Hz, three phase

RECOMMENDED ACCESSORIES

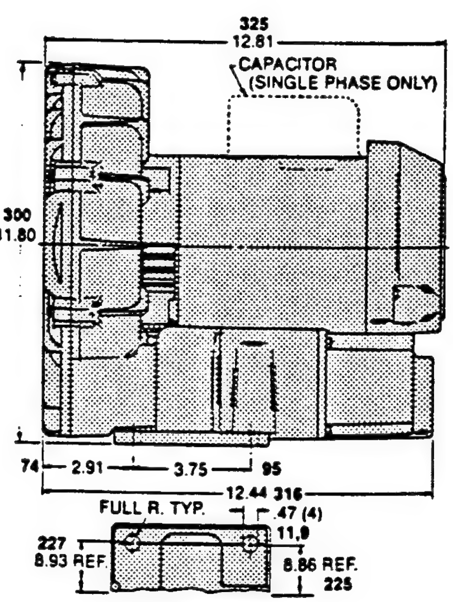
- Pressure gauge AJ496
- Filter AG338
- Muffler AJ121D
- Relief valve AG258

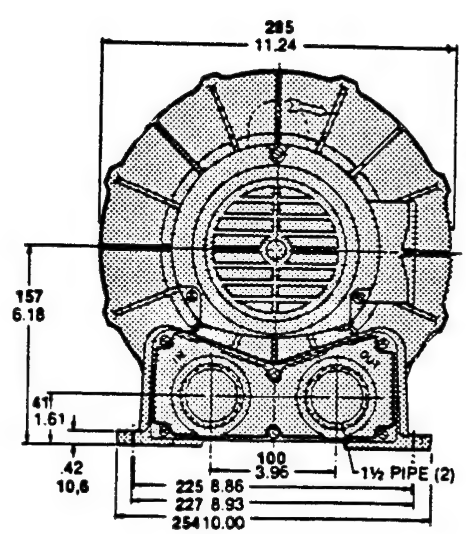
Various brand name motors are used on any model at the discretion of Gast Mfg. Corp.

Important Notice:

Pictorial and dimensional data is subject to change without notice.

Product Dimensions **Metric (mm) U.S. Imperial (inches)**



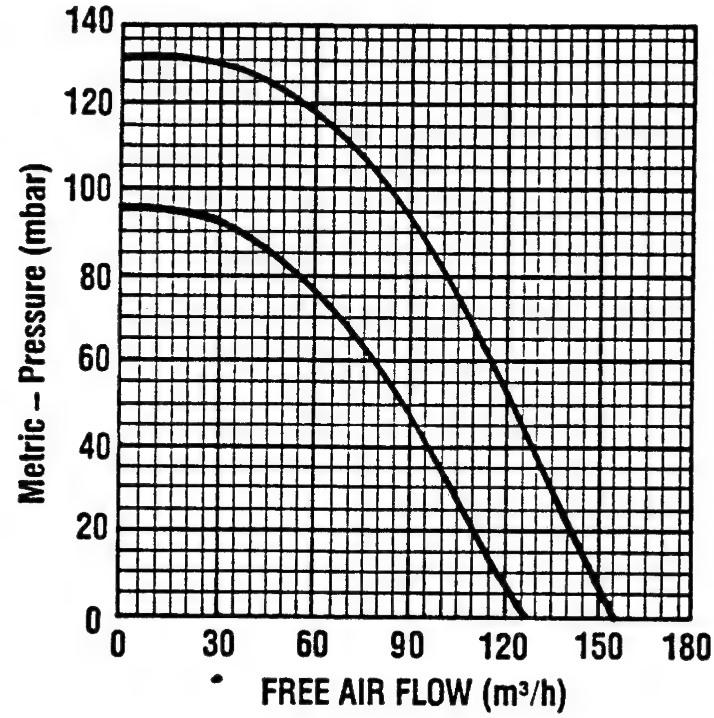


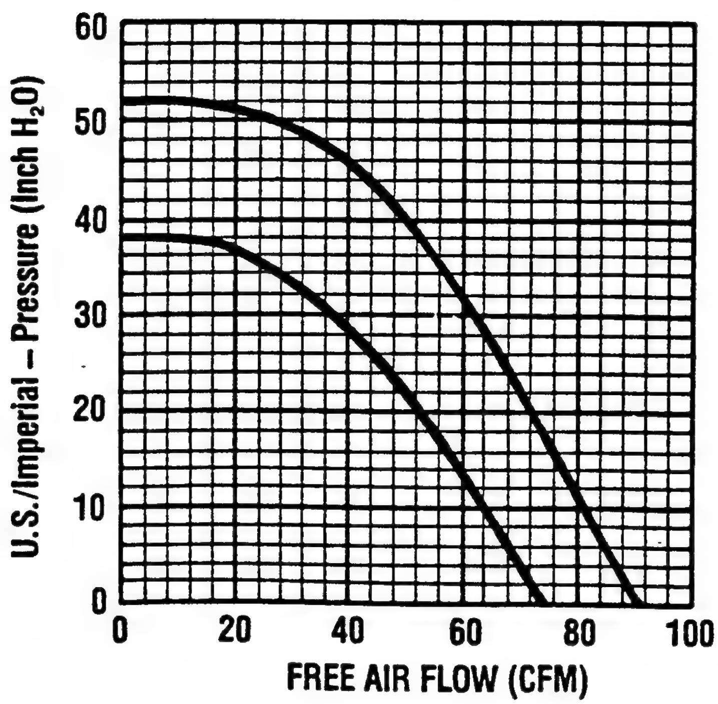
Product Specifications

Model Number	Motor Specs	Full Load Amps	HP	RPM	Max Pressure "H_2O	Max Pressure mbar	Max Flow cfm	Max Flow m³h	Net Wt. lbs.	Net Wt. kg
R4110-2	110/220-240-50-1	9.0/4.5-5.7	0.6	2850	38	95	74	126	41	18,6
	115/208-230-60-1	9.8/5.2-4.9	1.0	3450	52	130	92	156		
R4310A-2	190-220/380-415-50-3	2.6-3.3/1.3-1.4	0.6	2850	38	95	74	126	41	18,6
	208-230/460-60-3	3.4-3.2/1.6	1.0	3450	52	130	92	156		

Product Performance (Metric U.S. Imperial)

Black line on curve is for 60 cycle performance.
Blue line on curve is for 50 cycle performance.

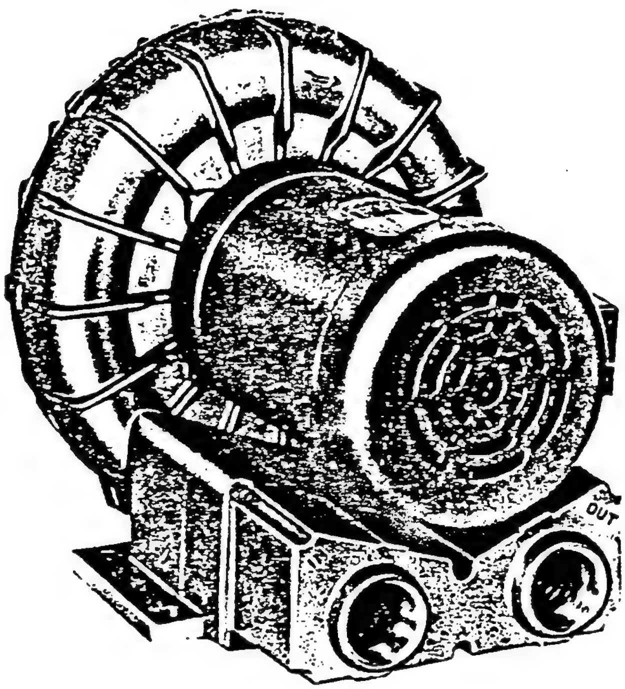




Oilless Regenerative Blowers, Motor Mounted to 160 cfm

GAST

REGENAIR® R5 Series



MODEL R5325A-2
65" H_2O MAX. PRESSURE, 160 CFM OPEN FLOW

PRODUCT FEATURES

- Oilless operation
- TEFC motor mounted
- Can be mounted in any plane
- Rugged construction/low maintenance

COMMON MOTOR OPTIONS

- 115/208-230V, 60 Hz, single phase
- 208-230/460V, 60 Hz; 190-220/380-415V, 50 Hz, three phase
- 575V, 60 Hz, three phase

RECOMMENDED ACCESSORIES

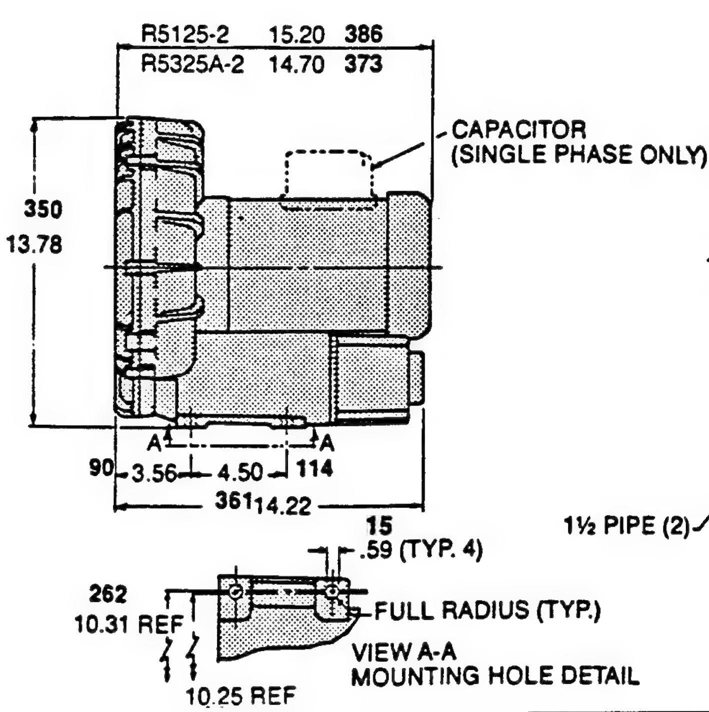
- Pressure gauge AE133
- Filter AG338
- Muffler AJ121D
- Relief valve AG258

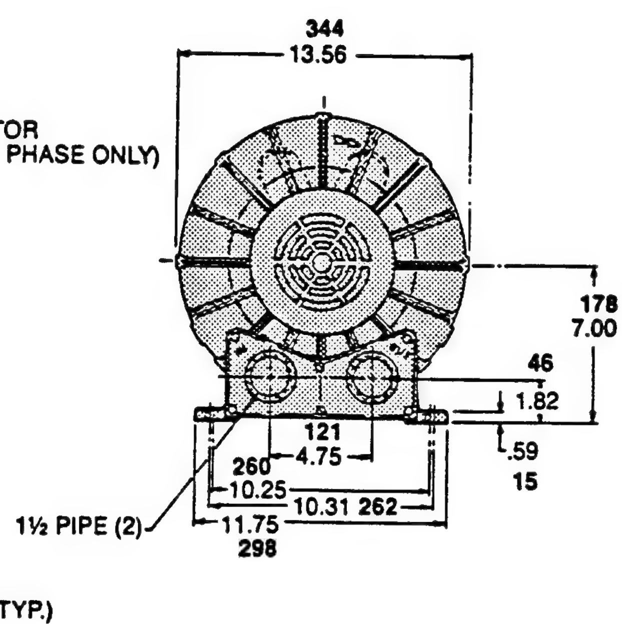
Various brand name motors are used on any model at the discretion of Gast Mfg. Corp.

Important Notice:

Pictorial and dimensional data is subject to change without notice.

Product Dimensions Metric (mm) U.S. Imperial (inches)



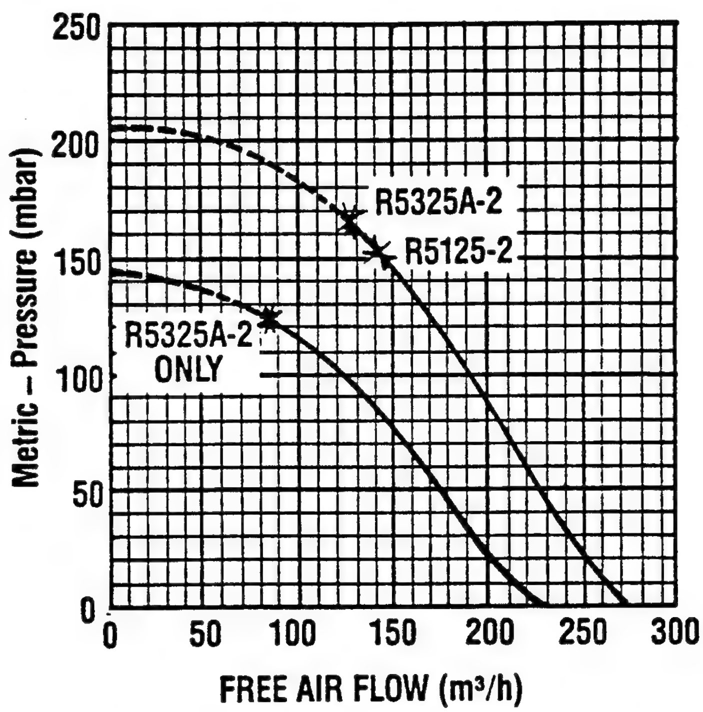


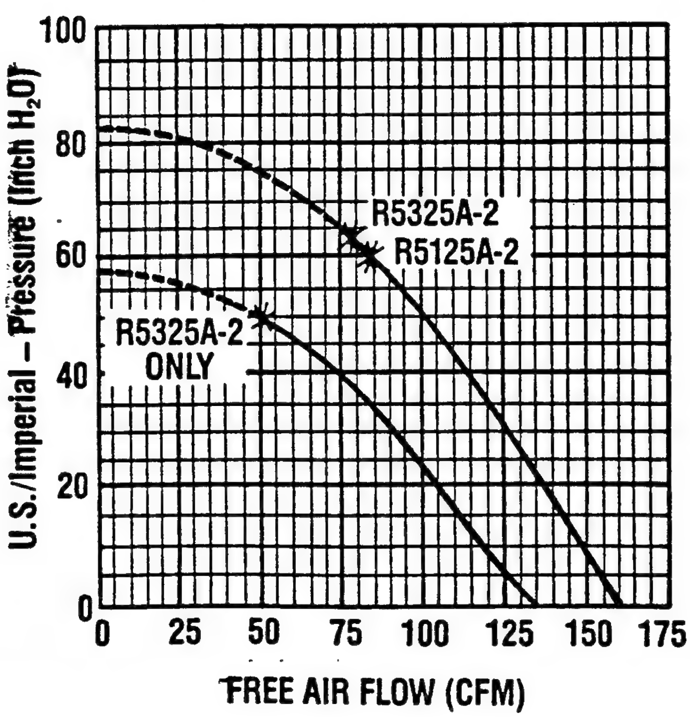
Product Specifications

Model Number	Motor Specs	Full Load Amps	HP	RPM	Max Pressure		Max Flow		Net Wt.	
					"H_2O	mbar	cfm	m³h	lbs.	kg
R5325A-2	190-220/380-415-50-3	6.6-6.7/3.3-3.5	1.35	2850	50	125	133	226	65	29,5
	208-230/460-3	6.9/3.45	2.5	3450	65	162	160	272		
R5125-2	115/208-230-60-1	22.4/12.4-11.2	2.5	3450	60	149	160	272	73	33,1

Product Performance (Metric U.S. Imperial)

Black line on curve is for 60 cycle performance.
Blue line on curve is for 50 cycle performance.





*Recommended maximum duty.
- - - - Intermittent duty only.

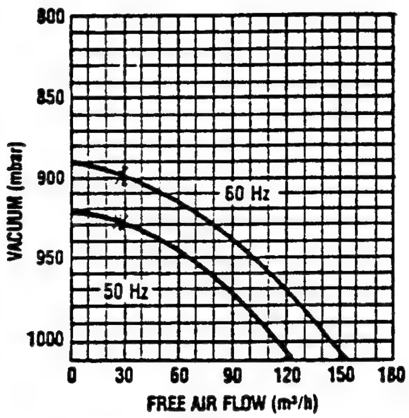
Product Specifications

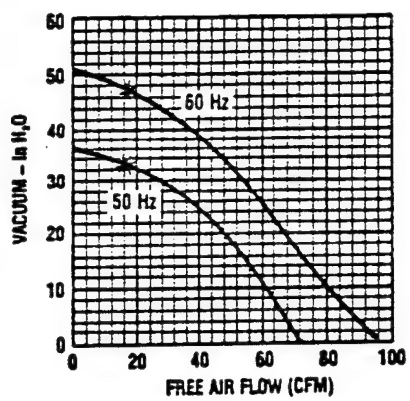
Model Number	Hz	Motor Specs	HP	RPM	Max Vac		Max Flow		Net Wt.	
					"H_2O	mbar	cfm	m³h	lbs.	kg
R4110N-50	50	110/220-240-50-1	0.6	2850	35	924	72	122	60	28
	60	115/208-230-60-1	1.0	3450	48	895	88	150		
R4310P-50	50	220/380-50-3*	0.6	2850	35	924	72	122	58	27
	60	208-230/460-60-3*	1.0	3450	48	895	88	150		
R5125Q-50	60	115/230-60-1*	2.5	3450	60	865	145	246	77	35
R5325R-50	50	190-220/380-415-50-3*	1.85	2850	47	897	120	204	75	34
	60	208-230/460-60-3*	2.50	3450	60	865	145	246		
R6P355R-50	50	190-220/380-415-50-3*	4.5	2850	70	840	235	400	247	112.
	60	208-230/460-60-3*	6.0	3450	90	790	260	442		

*Motors do not have thermal protection with automatic reset.

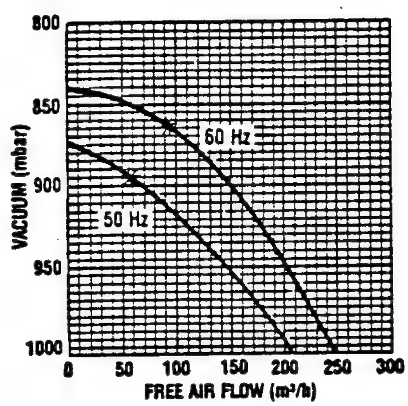
Product Performance (Metric U.S. Imperial)

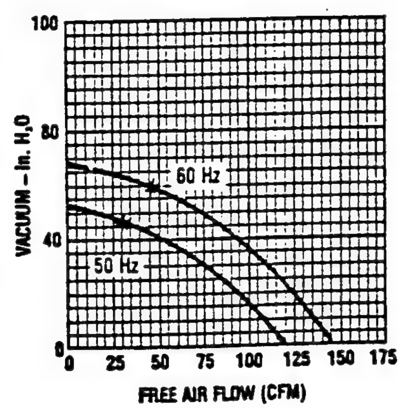
Model R4 Series



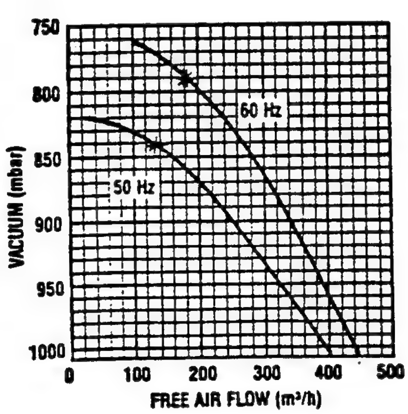


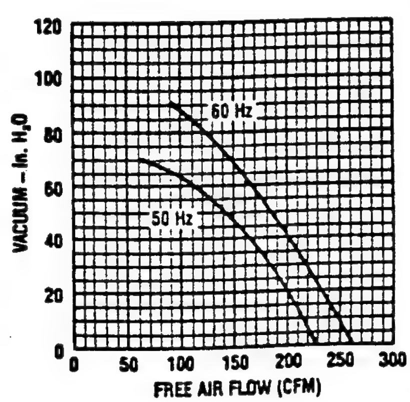
Model R5 Series





Model R6P Series

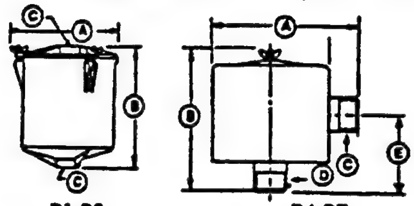




*Minimum flow permissible through the unit for trouble-free, continuous operation.

REGENAIR ACCESSORIES

Inline Filters (for vacuum)

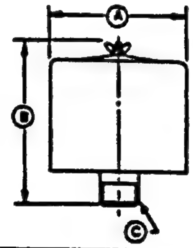


R1-R3 R4-R7

Model Number	R1 & R2	R3	R4, R5 &SDR4	R6P SDR5, SDR6 R6PP, R6PS	R7
Part #	AV460	AV460C	AG337	AJ151G	AJ151H
Dim A	8.25"	8.25"	11.75"	8.00"	16.25"
Dim B	8.875"	8.875"	4.75"	10.25"	27.13"
Dim C	1" FPT	1 1/4"FPT	1 1/2"MPT	2 1/2" MPT	3" MPT
Dim D	-	-	1 1/2" FPT	2 1/2"MPT	3" MPT
Dim E	-	-	2.38	5.50	18.50
Replacement Element	AV469	AV469	AG340	AJ135G	AJ135C
Micron	10	10	25	10	10

MPT = Male Pipe Thread
FPT = Female Pipe Thread

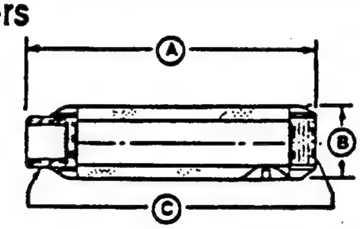
Inlet Filters (for pressure units only)



Model Number	R1 & R2	R3	R4, R5 &SDR4	R6, SDR5 SDR6, R6P R6PP, R6PS	R7
Part #	AJ126B	AJ126C	AG338	AJ126F	AJ126G
Dim A	6.00"	6.00"	10.63"	10.63"	10.00"
Dim B	4.62**	7.12**	4.81**	4.81**	13.12**
Dim C	1" MPT	1 1/4" MPT	1 1/2" FPT	2" FPT	2 1/2" MPT
Replacement Element	AJ134B	AJ134C	AG340	AG340	AJ135A
Micron	10	10	25	25	10

All are heavy duty for high amounts of particulates. Inlet filters for REGENAIR blowers are drip-proof when mounted as shown.

Mufflers



Model Number	R2	R3	R4, R5 SDR 4* &SDR5*	R6, SDR6* R6P R6PP, R6PS	R7
Part #	AJ121B	AJ121C	AJ121D	AJ121F	AJ121G
Dim. A	7.46**	7.94**	12.75**	17.05**	17.44**
Dim. B	2.38"	2.62"	3.25"	3.63"	4.25"
Dim. C	1" NPT	1 1/4" NPT	1 1/2" NPT	2" NPT	2 1/2" NPT

* For Inlet Only
** Approximately

Pressure-Vacuum Gauge

Pressure Gauge, Part #AJ496, 2 5/8" Diameter, 1/4" NPT, 0-60 inches H_2O and 0-150 mbar

Pressure Gauge, Part #AE133A, 2 5/8" Diameter, 1/4" NPT, 0-200 inches H_2O and 0-500 mbar

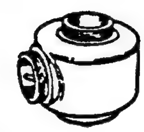
Vacuum Gauge, Part # #AJ497, 2 5/8" Diameter, 1/4" NPT, 0-60 inches H_2O and 0-150 mbar

Vacuum Gauge, Part #AE134, 2 5/8", Diameter, 1/4" NPT. 0-160 inches H_20 and 0-400 mbar

Fittings

Pipe Size	1"	1 1/4"	1 1/2"	2"	2 1/2"
Tee	BA415	BA431	BA432	BA433	BA434
Common Elbow	BA220	BA244	BA230	BA247	BA248
Nipple	BA752	BA809	BA783	BA810	BA813
Plastic Male Pipe Hose Barb	AJ117A	AJ117B	-	-	-
Hose I.D.	1.25	1.25	-	-	-
Metal Male Pipe Hose Barb	AJ117D	AJ117F	AJ117C	AJ117G	AJ117H
Hose I.D.	1.00	1.25	1.50	2.50	3.00

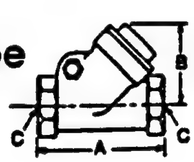
Relief Valve



Pressure/Vacuum Relief Valve, Part #AG258, 1 1/2" NPT, Adjustable 30-170 inches H_2O. 200 CFM maximum

Silencer for Relief Valve, Part #AJ121D

Horizontal Swing Type Check Valve



Model Number	R1, R2	R3	R4, R5 SDR 4 &SDR5	R6, SDR6 R6P R6PP, R6PS	R7
Part #	AH326B	AH326C	AH326D	AH326F	AH326G
Dim. A	3.57	4.19	4.50	5.25	8
Dim. B	2.32	2.69	2.94	3.82	5.07
Dim. C	1" NPT	1 1/4" NPT	1 1/2" NPT	2" NPT	2 1/2" NPT

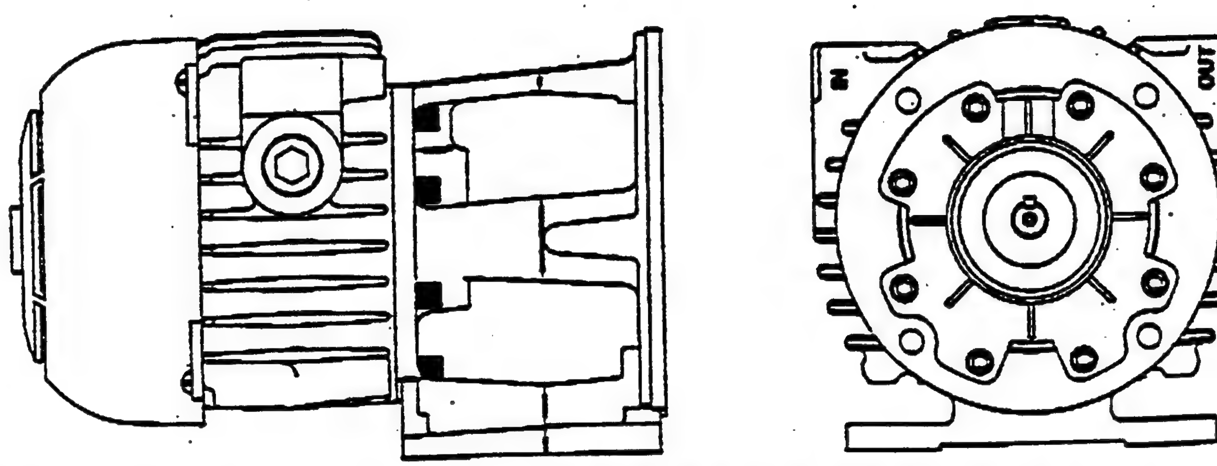
APPENDIX B
ROTARY-VANE BLOWER INFORMATION

70-230
G360PL
7-89

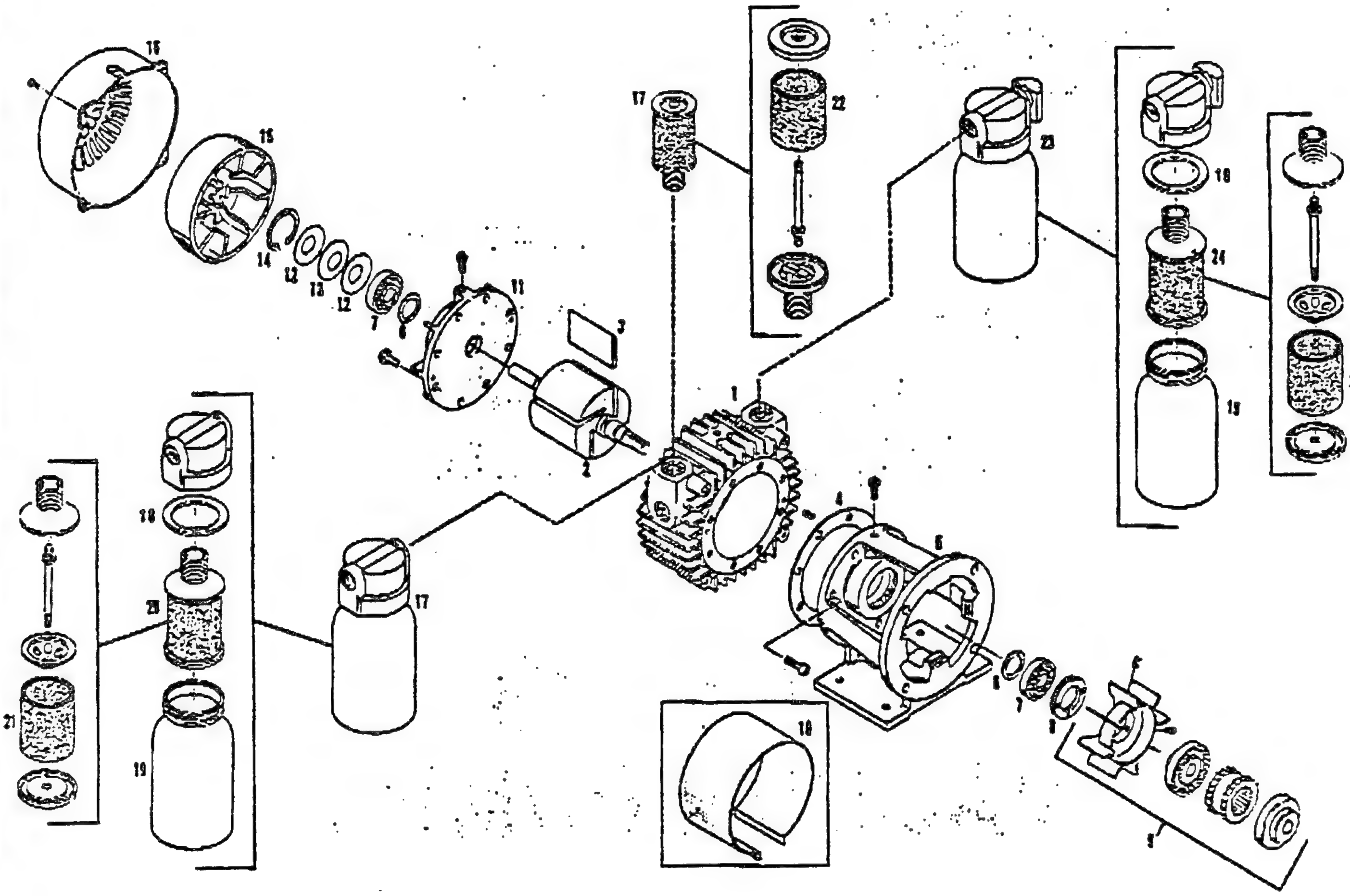
GAST MANUFACTURING CORPORATION
P. O. BOX 97, BENTON HARBOR, MICHIGAN 49022
PHONE 616-926-6171

PARTS LIST and OPERATING INSTRUCTIONS 1067, 2067, and 2567

OIL LESS VACUUM PUMPS and COMPRESSORS



WARNING: UNIT SHOULD NOT PUMP EXPLOSIVE GASES OR BE USED IN EXPLOSIVE AMBIENTS.



REF. NO.	DESCRIPTION	PART QNTY.	1067–V103	1067–P102	2067-V103	2067-P102	2567-V103	2567-P102
1	Body	1	AH348	AH340	AH191	AH191	AH300	AH333
2	Rotor Assembly	1	AH428	AH428	AH193	AH192	AH192	AH192
• 3	Vane	4	AH430	AH430	AH190	AH199	AH193	AH199
• 4	Body Gasket	1	AH587	AH587	AH587	AH587	AH587	AH587
5	Foot Bracket	1	AH208	AH208	AH208	AH208	AH208	AH208
• 6	Deflector	2	AH193	AH193	AH193	AH193	AH193	AH193
• 7	Ball Bearing (Drive & Dead)	2	AC894	AC894	AC894	AC894	AC894	AC894
8	End Cap, Drive	1	AB339A	AB339A	AB339A	AB339A	AB339A	AB339A
9	Fan Coupling Assembly	1	AH198	AH198	AH198	AH198	AH198	AH198
10	Fan Guard	1	AH194	AH194	AH194	AH194	AH194	AH194
11	End Plate Dead	1	AH205	AH205	AH205	AH205	AH205	AH205
12	Belleville Springs	2	AB337	AB337	AB337	AB337	AB337	AB337
13	Washer	1	AB338	AB338	AB338	AB338	AB338	AB338
14	Snap Ring	1	AB335	AB335	AB335	AB335	AB335	AB335
15	Fan	1	AC326B	AC326B	AC326B	AC326B	AC326B	AC326B
16	Fan Guard	1	AC1028	AC1028	AC1028	AC1028	AC1028	AC1028
17	Intake Filter Assembly	1	AA900C	AA905F	AA900D	AA905G	AA900D	AA905G
18	Gasket	2	AA405		AA405		AA405	
19	Jar	2	AA401		AA401		AA401	
20	Filter Assembly	1	AC435-1		AC435-1		AC435-1	
• 21	Cartridge	2	AC393	AC393	AC393		AC393	
• 22	Filter Felt	1		D3448		D3448		D3448
23	Muffler	1	AA900F		AA900F		AA900F	
24	Muffler Assembly	1	AC434-1		AC436-1		AC436-1	
	Service Kit		K355	K356	K360	K357	K360	K357

• Denotes parts in service kit.
When corresponding or ordering spare parts, please give complete model and serial numbers.

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OPERATING AND MAINTENANCE INSTRUCTIONS

CONSTRUCTION: The end plate, body, rotor and foot bracket are all cast iron. Consequently any moisture that accumulates in the pump will tend to corrode the interior especially if it stands idle. The vanes are made of hard carbon and are precision ground. They should last 5,000 to 10,000 hours depending upon the degree of vacuum pressure at which the pump is run.

STARTING: CAUTION: *NEVER LUBRICATE THIS OILLESS AIR PUMP.* The carbon vanes and grease packed motor bearings require no oil. If the motor fails to start or slows down when under load shut the unit off and unplug. Check that the supply voltage agrees with the motor post terminals and the motor data name plate. CAUTION: ALL DUAL VOLTAGE MOTORS ARE SHIPPED FROM THE FACTORY WIRED FOR THE HIGH VOLTAGE. If the pump is extremely cold allow it to warm to room temperature before starting. If anything appears to be wrong with the motor return the complete pump to an authorized Gast service facility.

To minimize noise and vibration the unit should be mounted on a solid surface that will not resonate. Use of shock mounts or vibration isolation material is recommended. Inlet or discharge noise can be minimized by attaching the muffler. The unit should not be allowed to operate in ambient air temperatures in excess of 40°C (104°F). If the motor fails to start or slows down when under load shut the unit off and unplug. Check that the supply voltage agrees with the motor post terminal setup and the motor data name plate.

FILTRATION: Care must be taken to insure that any particles (dirt, chips, foreign material) often found in new plumbing not be allowed to enter the unit. Liquid, moisture vapor, or oil based contaminates will affect pump performance and must be filtered from entering the pump.

Dirty filters restrict air flow and if not corrected could lead to possible motor overload, poor performance and early pump failure. Check filters periodically and clean when necessary by removing felts and washing in Gast flushing solvent (part number AH255). Dry with compressed air and replace.

FLUSHING: Should excessive dirt, foreign particles, moisture, or oil be permitted to enter the pump the vanes will act sluggish or even break. Flushing the pump should remove these materials. First remove the filter & muffler clean with solvent & dry with compressed air.

DISASSEMBLY: Begin by removing the fan guard and fan. The dead end plate may be removed using a wheel puller. The vanes and body area can then be inspected for damage or further cleaning. Unless scoring is visible do not remove drive end plate and top clearance will be maintained. If further repair is required remove the spanner nut before using a wheel puller to remove the drive end plate. Both bearings are a press fit on the shaft.

REASSEMBLY: First attach the drive end plate (but do not tighten bolts) and press the bearing on the shaft (be sure to properly support the inner race). If required top clearance (between rotor & body) should then be set (for 1067 models it is .0015 and for 2067 and 2567 it is .003). Now replace the dead end plate and bearing. Then the bellville springs, washer and snap ring should be replaced. With a dial indicator on the dead end shaft to show any movement, install spanner nut (with adhesive to keep from vibrating loose) until indicator moves .002–.0025. Check shaft for ease of rotation.

HAZARD PREVENTION:

WARNING: MAKE SURE THE ELECTRIC MOTOR IS PROPERLY GROUNDED AND THE WIRING IS DONE BY A QUALIFIED ELECTRICIAN FAMILIAR WITH NEMA MG2 SAFETY STANDARDS, NATIONAL ELECTRIC CODE AND ALL LOCAL SAFETY CODES.

WARNING: THE ELECTRIC MOTOR MAY BE THERMALLY PROTECTED AND WILL AUTOMATICALLY RESTART WHEN THE PROTECTOR RESETS.

WARNING: WHEN SERVICING ALL POWER TO THE MOTOR MUST BE DE-ENERGIZED AND DISCONNECTED. ALL ROTATING COMPONENTS MUST BE AT A STAND STILL.

WARNING: DO NOT USE KEROSENE OR OTHER COMBUSTIBLE SOLVENTS OR OPERATE PUMP IN EXPLOSIVE AMBIENTS.

Performance Data

Model	Vacuum			Maximum Vacuum
	0" HG	10" HG	20" HG	
1067	8.5 CFM	6.0 CFM	2.0	26" HG
2067	16.0	9.0	3.0	27"
2567	20.0	13.0	5.0	27"

Model	Pressure			
	0 PSI	5 PSI	10 PSI	15 PSI
1067	8.5 CFM	7.5 CFM	7.0 CFM	6.5 CFM
2067	17.0	14.0	12.0	11.0
2567	21.0	19.0	17.0	16.0

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High Wycombe, Bucks HP12 3SN
England 23571
FAX 444-943-6588

Gast Manufacturing Corp.
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Benton Harbor MI 49022
616/926-6171
FAX 616-925-8288

Gast Manufacturing Corp.
505 Washington Ave.
Carlstadt NJ 07072
201/933-8484
FAX 201-933-5545

Brenner-Fiedler & Assoc.
13824 Bentley Place
Cerritos, Ca. 90701
213-404-2721
FAX 213-404-7975

Wainbee, Ltd.
121 City View Drive
Rexdale, Ontario, Canada M9W 5A9
416/243-1900
FAX 416-243-2336

Wainbee, LTD.
215 Brunswick Blvd.
Pointe Claire, Montreal
Canada H9R 4R7
514/697-8810
FAX 514-697-3070

Note: All general correspondence should be directed to Gast Mfg Corp, P.O. Box 97, Benton Harbor, MI 49022

ACCESSORIES

CHECK VALVES—vacuum

AE238	¼" NPT, male
AJ550	¼" NPT, female
AJ550A	⅜" NPT, female

CHECK VALVES—vacuum swing

AH325A	¾" NPT
AH325B	1" NPT

CORDS—ELECTRIC

AA816	⅓" ½" ¾" hp, 115V without switch, 10 ft.
AA818	½" ¾" hp, 230V without switch, 10 ft.
AA898	⅙" ¼" ⅓" hp, 115 V with switch, 10 ft.

FILTERS—no jars

AC432	⅜" female NPS, 10 micron
AC430	½" male NPS, 10 micron
AC435	¾" male NPS, 10 micron
AA909B	⅜" female NPS, 80 micron
AA905F	½" male NPS, 80 micron
AA905G	¾" male NPS, 50 micron
B300A	¼" male NPS, 80 micron
B343B	¼" male NPS, 80 micron
AD750	1" male NPS, 30 micron

FILTERS—glass jar

AA817G	½" NPS, 2 oz., 80 micron
AA922H	¼" NPS, ¾" oz., 80 micron
AD560	1" NPS, 2 qt., 80 micron
AB580	¾" NPS, 1 pt., 10 micron
AB599D	⅜" NPS, 1 pt., 80 micron
AB600	½" NPS, 1 pt., 80 micron
AB600F	½" NPS, 1 pt., 10 micron
AB601B	¾" NPS, 1 pt., 10 micron
AB601C	¾" NPS, 1 pt., 80 micron
AA800C	½" NPS, 1 qt., 10 micron
AA800E	½" NPS, 1 qt., 80 micron
AA900D	¾" NPS, 1 qt., 10 micron
AA900J	¾" NPS, 1 qt., 80 micron
V400G	¼" NPS, 8 oz., 80 micron
V500D	⅜" NPS, 8 oz., 30 micron
V400C	¼" NPS, 8 oz., 80 micron

FILTERS—metal jar

AB609D	¼" NPS, ½" pt., 10 micron
AB612	½" NPS, ½" pt., 10 micron
AB808B	⅜" NPS, ½" pt., 10 micron
AB809	¼" NPS, ½" pt., 80 micron
AB608	⅜" NPS, ½" pt., 80 micron
AB650C	¾" NPS, 1 qt., 10 micron
AB650G	¾" NPS, 1 qt., 80 micron
AB665	½" NPS, 1 qt., 80 micron
AB665B	½" NPS, 1 qt., 10 micron

FILTERS—plastic jar

AA922N	¼" NPS, ¾" oz.
V400H	¼" NPS, 8 oz.
V500N	⅜" NPS, 8 oz.

FLUSHING SOLVENT

AH255	1 qt.

FOOT SUPPORT ASSEMBLIES

AC136	0211, 0322, 0522
AE240	¼"-¾" hp piston pumps
AE241	½"-¾" piston pumps
AE243	¼" hp piston pumps

GAUGES—pressure

AA842	¼" NPS, 0-30 psi
AA844B	¼" NPS, 0-30 psi 0-2K/cm²
AA806	¼" NPS, 0-160 psi (back mount)
AA807	¼" NPS, 0-160 psi (back mount)
AP583	¼" NPS, 0-100 psi, heavy duty (bottom mount)

GAUGES—vacuum

AA840	¼" NPS, 0-30" Hg, 0-760 m/m Hg
AA841	¼" NPS, 0-30" Hg

HANDLES—carrying

AP535	for ½" and ¾" hp units

MUFFLERS—glass jar

AB599B	⅜" NPS, 1 pt., 10 micron, for oil-less pumps
AB600C	½" NPS, 1 pt., 80 micron, for oil-less pumps
AB600J	½" NPS, 1 pt., 30 micron, for oil-less pumps
AD560	1" NPS, 2 qt., 50 micron
AD560B	1" NPS, 2 qt., 80 micron, with fitting for quieter operation
AA900F	¾" NPS, 1 qt., 10 micron, for oil-less pumps
AA900G	¾" NPS, 1 qt., 80 micron, for oil-less pumps
AA922B	¼" NPS, ¾" oz., 80 micron, for oil-less pumps
AA922G	same as AA922 but with silencing tube
AA817F	½" NPS, 2 oz., 80 micron, for oil-less pumps

MUFFLERS—metal jar

AB612A	½" NPS, ½" pt., 10 micron
AB609B	¼" NPS, ½" pt., 10 micron
AB808A	⅜" NPS, ½" pt., 10 micron
AB663C	½" NPS, 1 qt., 10 micron
AB650D	¾" NPS, 1 qt., 10 micron

MUFFLERS—plastic jar

AA922P	¼" NPS, ¾" oz.
V425M	¼" NPS, 8 oz.
V525G	⅜ NPS, 8 oz.

OVERLOADS—motor

	External thermal protector, specify motor number and make

PAINT

AE564A	Gast blue-gray, 16 oz. aerosol can

RELIEF VALVES—pressure

AA203	¼" NPS, flow below 2 cfm
AA205	¼" NPS, flow below 2 cfm
AA800	⅜" NPS, flow below 10 cfm
AA307	¾" NPS, flow above 10 cfm
AF570S	¼" NPS, 0-100 psi
AF720	¼" NPT, 0-100 psi
AE960	1" NPT, 0-100 psi.

RELIEF VALVES—vacuum

AA204	¼" NPS, flow below 2 cfm
AA207	¼" NPS, flow below 2 cfm
AA840A	⅜" NPS, flow from 2-10 cfm
AA308	¾" NPS, flow above 10 cfm
AE961	1" NPS, for 4565, 5565

SWITCH—vacuum

AE285	¼" NPS

TRAPS—vacuum

AA873	¼" NPS, 8 oz.
AA873B	½" NPS, 2 oz.
AA875C	¼" NPS, 2 oz.

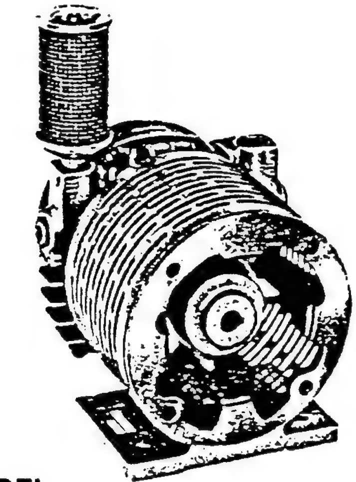
TROUBLE SHOOTING GUIDE FOR ROTARY VANE PUMPS

REASONS FOR PROBLEM	Low Vac.	Low Press.	High Vac.	High Press.	Pump Overheating	Motor Overload
Filter dirty	X	X	at pump		X	X
Muffler dirty		X		at pump	X	X
Vac. line collapsed	X		at pump		X	X
Relief valve set too high			X	X	X	X
Relief valve set too low	X	X				
Plugged vacuum or pressure line	X	X	at pump	at pump	X	X
Vanes sticking	X	X				
Running at too high RPM			X	X	X	X
Vanes worn (replace)	X	X				
Shaft seal worn (replace)	X	X				
Dust or offset powder in pump	X	X			X	X
Motor not wired correctly	X	X			X	

Separate Drive Rotary Vane 8.5, 17.0 and 21.0 cfm

GAST

Oilless 1067, 2067, 2567 Series



MODEL 1067 SERIES
15 PSI MAX. PRESSURE, 8.50 CFM OPEN FLOW

MODEL 2067 SERIES
15 PSI MAX. PRESSURE, 17.00 CFM OPEN FLOW

MODEL 2567 SERIES
15 PSI MAX. PRESSURE, 21.00 CFM OPEN FLOW

PRODUCT FEATURES

- Oilless operation
- Close coupled easy motor mounting
- Rugged construction/low maintenance
- Essentially pulse free service

INCLUDES

- Filter AA905F (1067), AA905G (2067/2567)
- Fan/coupling assembly AH198
- Fan guards AC102C, AH194

RECOMMENDED ACCESSORIES

- ~~Pressure relief valve~~ AA600 (1067), AA307 (2067/2567) (U.S. version)
- ~~Pressure gauge~~ AA644B (U.S. version)
- Repair kit K356 (1067)
- Repair kit K350 (2067/2567)

Important Notice:

Pictorial and dimensional data is subject to change without notice.

EUROPEAN MODEL
Product Dimensions Metric (mm)

Model	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1067	195	100	144	72	288	180	102	11	125	165	241	142	19	80
2067	195	100	144	72	289	180	102	11	125	165	284	164	19	80
2567	195	100	144	72	289	180	102	11	125	165	284	164	19	80

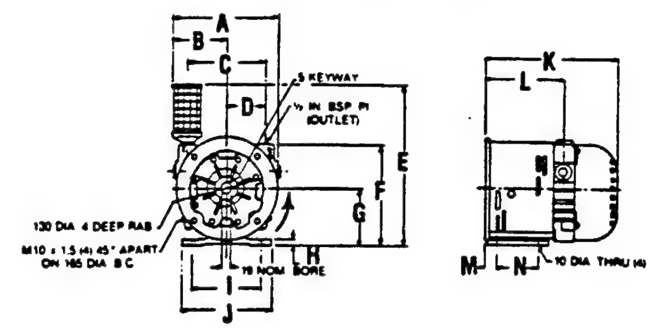
U.S. MODEL
Product Dimensions Metric (mm) U.S. Imperial (inches)

Model	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1067	195	145	287	180	132	102	11	124	165	241	142	495	21	76
1067	7.69	5.69	11.31	7.09	5.19	4.0	.44	4.88	6.50	9.50	5.59	19.50	.84	3.00
2067	194	145	287	180	132	102	11	124	165	284	164	584	21	76
2067	7.63	5.69	11.31	7.09	5.19	4.0	.44	4.88	6.50	11.19	6.44	23.00	.84	3.00
2567	194	145	287	180	132	102	11	124	165	284	164	584	21	76
2567	7.63	5.69	11.31	7.09	5.19	4.0	.44	4.88	6.50	11.19	6.44	23.00	.84	3.00

Dimensions for reference only.

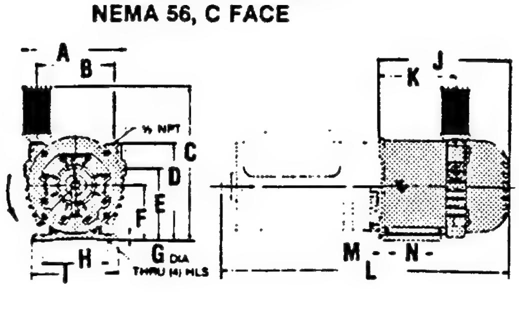
METRIC MODEL

INLET
2067/2567 ¾ IN. BSP.
1067 ½ IN. BSP.



U.S./IMPERIAL MODELS
NEMA 56, C FACE

INLET
2067/2567 ¾ NPT
1067 ½ NPT



Product Specifications

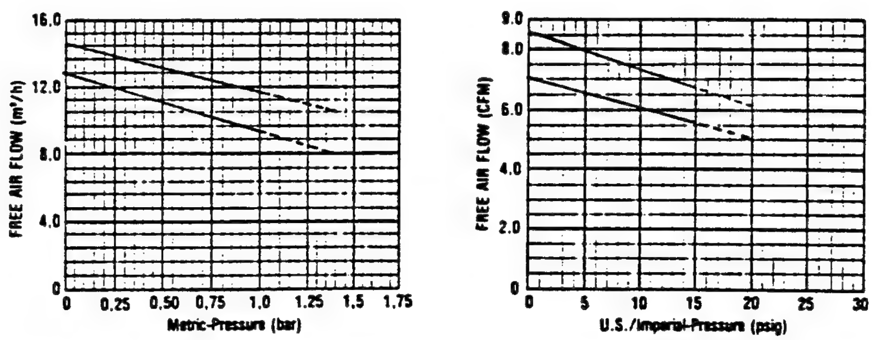
Model Number	Motor	RPM 60 cycle	RPM 50 cycle	HP	kW	Net Wt. lbs.	Net Wt. kg
1067-P102	Not included	1725	1425	1	0,75	34	15,40
1067-P104 (metric)	Not included	1725	1425	1	0,75	34	15,40
†1067-P106-G561X (like 1067-P102 plus motor)	110/220-240; 115/208-230; 50/60-1	1725	–	1	0,75	65	29,5
2067-P102	Not included	1725	1425	1	0,75	47	21,3
2067-P104 (metric)	Not included	1725	1425	1	0,75	47	21,3
†2067-P106-G561X (like 2067-P102 plus motor)	110/220-240; 115/208-230; 50/60-1	1725	–	1	0,75	92	41,7
2567-P102	Not included	1725	1425	2	1,5	46	20,9
2567-P104 (metric)	Not included	1725	1425	2	1,5	46	20,9
2567-P106-G475 (like 2567-P102 plus motor)	230/460-60-3	1725	–	2	1,5	81	36,8

†Motor includes Thermotector.

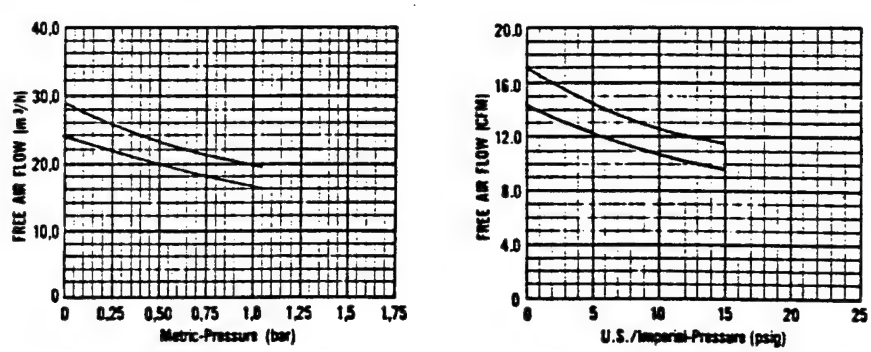
Product Performance (Metric U.S. Imperial)

Black line on curve is for 60 cycle performance.
Blue line on curve is for 50 cycle performance.

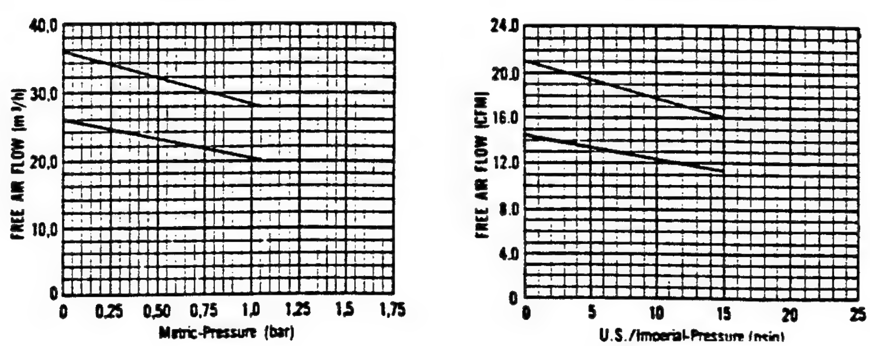
Model 1067



Model 2067



Model 2567



APPENDIX C
DATA COLLECTION SHEETS

BLOWER MAINTENANCE RECORD (INJECTION)

Site: Fuel Storage Area G

Location: Travis AFB, CA

		WEEKLY				MONTHLY				
	Date	Blower Running ? ** (Y/N)	Inlet Vacuum[1] (in. H_2O)	Outlet Pressure[2] (in. H_2O)	Outlet Temp.[3] (°F)	Check Filters ? (Y/N)	Clean/Replace Filters ? (Y/N)	FAXed log ? (Y/N)	Comments	Init.
Ex:	06/11/93	Y	2.5	45	120	Y	Y	Y	excessive dirt on paper filter	MBP

** If blower is not running, immediately contact Fred Stanin, Engineering–Science, (510) 769–0100.

[1] If inlet vacuum exceeds 20 inches of water, shut blower down and contact Engineering–Science.

[2] If outlet pressure exceeds 50 inches of water, shut blower down and contact Engineering–Science.

[3] If outlet temperature exceeds 160°F, shut blower down and contact Engineering–Science.

NOTE: Once a month, this sheet must be FAXed to: Fred Stanin, Engineering–Science, (510) 769–9244.

reg_inj

06/17/93

BLOWER MAINTENANCE RECORD (INJECTION)

Site: Fuel Storage Area G

Location: Travis AFB, CA

		WEEKLY				MONTHLY				
	Date	Blower Running ? ** (Y/N)	Inlet Vacuum[1] (in. H_2O)	Outlet Pressure[2] (in. H_2O)	Outlet Temp.[3] (°F)	Check Filters ? (Y/N)	Clean/Replace Filters ? (Y/N)	FAXed log ? (Y/N)	Comments	Init.
Ex:	06/11/93	Y	2.5	45	120	Y	Y	Y	excessive dirt on paper filter	MBP

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reg_inj
06/17/93

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Site: Fuel Storage Area G

Location: Travis AFB, CA

	Date	WEEKLY				MONTHLY			Comments	Init.
		Blower Running ? ** (Y/N)	Inlet Vacuum[1] (in. H_2O)	Outlet Pressure[2] (in. H_2O)	Outlet Temp.[3] (°F)	Check Filters ? (Y/N)	Clean/Replace Filters ? (Y/N)	FAXed log ? (Y/N)		
Ex:	06/11/93	Y	2.5	45	120	Y	Y	Y	excessive dirt on paper filter	MBP

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reg_inj

06/17/93

BLOWER MAINTENANCE RECORD (INJECTION)

Site: Fuel Storage Area G

Location: Travis AFB, CA

	Date	Blower Running ? ** (Y/N)	Inlet Vacuum[1] (in. H_2O)	Outlet Pressure[2] (in. H_2O)	Outlet Temp.[3] (°F)	Check Filters ? (Y/N)	Clean/Replace Filters ? (Y/N)	FAXed log ? (Y/N)	Comments	Init.
		WEEKLY				MONTHLY				
Ex:	06/11/93	Y	2.5	45	120	Y	Y	Y	excessive dirt on paper filter	MBP

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BLOWER MAINTENANCE RECORD (INJECTION)

Site: Fuel Storage Area G

Location: Travis AFB, CA

		WEEKLY				MONTHLY				
	Date	Blower Running ? ** (Y/N)	Inlet Vacuum[1] (in. H_2O)	Outlet Pressure[2] (in. H_2O)	Outlet Temp.[3] (°F)	Check Filters ? (Y/N)	Clean/Replace Filters ? (Y/N)	FAXed log ? (Y/N)	Comments	Init.
Ex:	06/11/93	Y	2.5	45	120	Y	Y	Y	excessive dirt on paper filter	MBP

** If blower is not running, immediately contact Fred Stanin, Engineering–Science, (510) 769–0100.

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reg_inj
06/17/93

APPENDIX C

CHAIN OF CUSTODY FORMS

CHAIN OF CUSTODY RECORD

ENGINEERING-SCIENCE, INC.
1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290
303-831-8100

ES Job No. DE268. 21 .08

AFCEE BIOVENTING PILOT TESTS

Base: Travis AFB

Site: 1 Area 6

Sampler(s): (Signature) Henry Pietrzyk

Ship To:
ENGINEERING-SCIENCE LABORATORY
600 Bancroft Way
Berkeley, CA 94710

Attn: Tom Paulson
(510) 841-7353

Preservative: NONE (SW 9045, A 403, SW 7380, SW 846); HOLD AT 4C (SW 8020, E 418.1); NONE (E 351.2, E 365.3, UCM)

Analysis Required

Date	Time	Sample Description	Lab I.D.	No. of Contrs.	SW 9045 (PH)	A 403 (ALKA)	SW 7380 (IRON)	SW 846 (MOIST)	SW 8020 (BTEX)	E 418.1 (TRPH)	E 351.2 (TKN)	E 365.3 (PHOS)	UCM (CLASS)	Sample Type	Matrix	Remarks
2/16/93	1020	TRI - VEW1 - 6		2	X	X	X	X	X	X	X	X	X	G C	SOIL	
2/16/93	1137	TRI - VMP1 - 6		2	X	X	X	X	X	X	X	X	X	G C	SOIL	
2/16/93	1331	TRI - VMP2 - 6		2	X	X	X	X	X	X	X	X	X	G C	SOIL	
2/16/93	1331	TRI - VMP2 - 9		1					X	X				G C	SOIL	Analyze TRPH, BTEX only
2/17/93	1052	TRI - VMP4 - 6		1							X			G C	SOIL	Analyze TKN only
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	Temp. 5°C

Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time
Henry Pietrzyk	2/18/93 / 1650	[signature]	2/18/93 / 1650
Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time

Remarks:

G - Grab Sample, C - Composite Sample

Distribution: Original Accompanies Shipment. Copies to: Coordinator Field Files

Federal Express Number: ____

Airbill Number: ____

ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900 • Denver, Colorado
(303) 831-8100

Fi[illegible] C.2

CHAIN OF CUSTODY RECORD

ENGINEERING-SCIENCE, INC.
1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290
303-831-8100

ES Job No.
DE268.__ __.08

AFCEE BIOVENTING PILOT TESTS

Base: Travis AFB, Calif.

Site: South Gas Station

Sampler(s): (Signature) Henry Pietropaoli E E Rosenberg E.E. Rosenberg

Preservative: NONE | HOLD AT 4C | NONE

Ship To:

ENGINEERING-SCIENCE LABORATORY
600 Bancroft Way
Berkeley, CA 94710

Attn: Tom Paulson
(510) 841-7353

Analysis Required

Date	Time	Sample Description	Lab I.D.	No. of Contrs.	SW 9045 (PH)	A 403 (ALKA)	SW 7380 (IRON)	SW 846 (MOIST)	SW 8020 (BTEX)	E 418.1 (TRPH)	E 351.2 (TKN)	E 365.3 (PHOS)	UCM (CLASS)	Sample Type	Matrix	Remarks
12/8/92	1110	TRsgs – VMP-1 – 15.5		2	X	X	X	X	X	X	X	X	X	G C	SOIL	CAll Fred Stamen
12/8/92	1208	TRsgs – VEW-1 – 15.5		2	X	X	X	X	X	X	X	X	X	G C	SOIL	ES-Alameda before
12/8/92	1409	TRsgs – VMP-2 – 15.5		2	X	X	X	X	X	X	X	X	X	G C	SOIL	analyzing samples.
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
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Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time
[signature]	12/9/92 7:12	[signature]	12/9/92 7:12 AM

Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time

Remarks:

G - Grab Sample, C - Composite Sample

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Airbill Number: __________

ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900 • Denver, Colorado
(303) 831-8100

CCRSOIL

C[redacted]N O[redacted]UST[redacted]Y R[redacted]OR[redacted]

ENGINEERING-SCIENCE, INC. 1700 BROADWAY, SUITE 900 DENVER, COLORADO 80290 303-831-8100	AFCEE BIOVENTING PILOT TESTS Base: Travis AFB Site: South Gas Station (SGS)
ES Job No. DE268. 2 1 .08	

Ship To:

AIR TOXICS LTD.
11325 Sunrise Gold Circle, Suite 4
Rancho Cordova, CA 95742

Attn: Bob Freeman
(916) 638-9892

Sampler(s): (Signature)
M.B. Phelps
P.R. Guest

Preservative: NONE

Analysis Required

Date	Time	Sample Description	Lab I.D.	No. of Contrs.	TO-3(EPA)	(BTEX & TPH)	Sample Type	Matrix	Remarks
2/22/93	1630	TRSGS-VEW1-5/15		1	✓	✓	G C	AIR	TPH as gasoline
2/22/93	1630	TRSGS-VMPZ-14		1	✓	✓	G C	AIR	TPH as gasoline
2/23/93	1450	TRSGS-VEW1-5/15 (PP)		1	✓	✓	G C	AIR	TPH as gasoline
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
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							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	

Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time
	3/1/93 1700		
Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time

Remarks:

G - Grab Sample, C - Composite Sample

Distribution: Original Accompanies Shipment. Copies to: Coordinator Field Files

Federal Express Number: ________

Airbill Number: ________

ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900 • Denver, Colorado
(303) 831-8100

CCRAIR

ES Alameda contact: Fred Stanin (510) 769-0100

Figure

CHAIN OF CUSTODY RECORD

Page ____ of ____

ENGINEERING-SCIENCE, INC.
1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290
303-831-8100

AFCEE BIOVENTING PILOT TESTS

Base: Travis AFB

Site: 1, FSG

ES Job No. DE268. 21 .08

Preservative: NONE

Ship To:
AIR TOXICS LTD.
11325 Sunrise Gold Circle, Suite 4
Rancho Cordova, CA 95742

Attn: Bob Freeman
(916) 638-9892

Sampler(s): (Signature) E. E Rosenberg, Michael B. Phelps

Analysis Required

Date	Time	Sample Description	Lab I.D.	No. of Contrs.	TO-3(EPA)	(BTEX & TPH)	Sample Type	Matrix	Remarks
6/7/93	1750	TRI-VMP1-6.5		1	✓	✓	G C	AIR	TPH as jet fuel
6/7/93	1757	TRI-VW1-8		1	✓	✓	G C	AIR	
6/8/93	1015	TRI-VMP3-6.5		1	✓	✓	G C	AIR	
6/7/93	2010	TRI-BKT-1		1	✓	✓	G C	AIR	
6/8/93	2025	TRI-BKT-2		1	✓	✓	G C	AIR	
							G C	AIR	for questions,
							G C	AIR	contact
							G C	AIR	Fred Stanin
							G C	AIR	at Engineering-Science
							G C	AIR	
							G C	AIR	(510) 769-0100
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	

Relinquished by: (Signature)	Date / Time	Recieved ~~for Laboratory~~ by: (Signature)	Date / Time
[signature]	6/15/93 1630	UPS (UPS) (signature in book)	
Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time

Remarks:

G - Grab Sample, C - Composite Sample

Distribution: Original Accompanies Shipment. Copies to: Coordinator Field Files

Federal Express Number: ____

Airbill Number: ____

ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900 • Denver, Colorado
(303) 831-8100

CCRAIR

APPENDIX D

BIODEGRADATION RATE CALCULATIONS

BIODEGRADATION RATE CALCULATIONS

Site: South Gas Station
Location: Travis AFB, California
Soil Smpl.Depth: 15.5 ft. bgs
VEW/VMP: VEW-1

Measurements and Assumptions			
ko	Oxygen Utilization Rate (%/hr)	2.90	assumed from measured value for VEW-2 ISR test
W	Moisture Content	0.187	laboratory measurement
	Soil Type	SAND;loose,damp	field observation
Gs	Specific Gravity (grain density)	2.65	estimated based on Gs of quartz
n	Porosity	0.40	estimated from soil type
	TRPH + BTEX Concentration (mg/kg)	58.4	laboratory measurement
Constants			
Yw	Unit Weight of Water (g/cm3)	1.00	known constant
Do	Density of Oxygen (mg/L)	1340	known constant
C	Carbon/Oxygen Ratio	0.29	assumed 1/3.5 mass ratio required for degradation
Calculated Data			
Yd	Dry Unit Weight (g/cm3)	1.59	Yw x Gs (1 - n)
Vv	Volume of Voids (L/L soil)	0.40	n x 1 liter
e	Void Ratio	0.67	n / (1-n)
S	Degree of Saturation	0.74	Gs (W / e)
Vw	Volume of Water (L/L soil)	0.30	S x Vv
Va	Volume of Air (L/L soil)	0.10	Vv - Vw
p	Bulk Density (kg/L soil)	1.89	Yd + (Vw x Yw) or Yw[Gs+(S x e)] / 1+e 1.89
A	Air Filled Volume (L air/kg soil)	0.054	Va / p
Kb	**Biodegradation Rate (mg TPH/kg soil/yr)**	**5291**	**(ko x A x Do x C x 8760 hr per yr) / 100**

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BIODEGRADATION RATE CALCULATIONS

Site: South Gas Station
Location: Travis AFB, California
Soil Smpl.Depth: None
VEW/VMP: VMP-1-6

Measurements and Assumptions			
ko	Oxygen Utilization Rate (%/hr)	2.20	calculated from field ISR test
W	Moisture Content	0.150	estimated from soil type
	Soil Type	SILT;clay-rich	field observation
Gs	Specific Gravity (grain density)	2.65	estimated based on Gs of quartz
n	Porosity	0.35	estimated from soil type
	TRPH + BTEX Concentration (mg/kg)		
Constants			
Yw	Unit Weight of Water (g/cm3)	1.00	known constant
Do	Density of Oxygen (mg/L)	1340	known constant
C	Carbon/Oxygen Ratio	0.29	assumed 1/3.5 mass ratio required for degradation
Calculated Data			
Yd	Dry Unit Weight (g/cm3)	1.72	Yw x Gs (1 - n)
Vv	Volume of Voids (L/L soil)	0.35	n x 1 liter
e	Void Ratio	0.54	n / (1-n)
S	Degree of Saturation	0.74	Gs (W / e)
Vw	Volume of Water (L/L soil)	0.26	S x Vv
Va	Volume of Air (L/L soil)	0.09	Vv - Vw
p	Bulk Density (kg/L soil)	1.98	Yd + (Vw x Yw) or Yw[Gs+(S x e)] / 1+e 1.98
A	Air Filled Volume (L air/kg soil)	0.046	Va / p
Kb	**Biodegradation Rate (mg TPH/kg soil/yr)**	**3413**	**(ko x A x Do x C x 8760 hr per yr) / 100**

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BIODEGRADATION RATE CALCULATIONS

Site: South Gas Station
Location: Travis AFB, California
Soil Smpl.Depth: 15.5 ft.bgs
VEW/VMP: VMP-1-14

Measurements and Assumptions			
ko	Oxygen Utilization Rate (%/hr)	2.20	assumed from measured value for VMP-1-6
W	Moisture Content	0.123	laboratory measurement
	Soil Type	SAND;loose,fine	field observation
Gs	Specific Gravity (grain density)	2.65	estimated based on Gs of quartz
n	Porosity	0.40	estimated from soil type
	TRPH + BTEX Concentration (mg/kg)	82.9	
Constants			
Yw	Unit Weight of Water (g/cm3)	1.00	known constant
Do	Density of Oxygen (mg/L)	1340	known constant
C	Carbon/Oxygen Ratio	0.29	assumed 1/3.5 mass ratio required for degradation
Calculated Data			
Yd	Dry Unit Weight (g/cm3)	1.59	Yw x Gs (1 - n)
Vv	Volume of Voids (L/L soil)	0.40	n x 1 liter
e	Void Ratio	0.67	n / (1-n)
S	Degree of Saturation	0.49	Gs (W / e)
Vw	Volume of Water (L/L soil)	0.20	S x Vv
Va	Volume of Air (L/L soil)	0.20	Vv - Vw
p	Bulk Density (kg/L soil)	1.79	Yd + (Vw x Yw) or Yw[Gs+(S x e)] / 1+e 1.79
A	Air Filled Volume (L air/kg soil)	0.114	Va / p
Kb	**Biodegradation Rate (mg TPH/kg soil/yr)**	**8447**	**(ko x A x Do x C x 8760 hr per yr) / 100**

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BIODEGRADATION RATE CALCULATIONS

Site: South Gas Station
Location: Travis AFB, California
Soil Smpl.Depth: None
VEW/VMP: VMP-2-6

Measurements and Assumptions			
ko	Oxygen Utilization Rate (%/hr)	2.30	calculated from field ISR test
W	Moisture Content	0.210	estimated from soil type
	Soil Type	CLAY;damp,plastic, mod stiff	field observation
Gs	Specific Gravity (grain density)	2.65	estimated based on Gs of quartz
n	Porosity	0.40	estimated from soil type
	TRPH + BTEX Concentration (mg/kg)		
Constants			
Yw	Unit Weight of Water (g/cm3)	1.00	known constant
Do	Density of Oxygen (mg/L)	1340	known constant
C	Carbon/Oxygen Ratio	0.29	assumed 1/3.5 mass ratio required for degradation
Calculated Data			
Yd	Dry Unit Weight (g/cm3)	1.59	Yw x Gs (1 - n)
Vv	Volume of Voids (L/L soil)	0.40	n x 1 liter
e	Void Ratio	0.67	n / (1-n)
S	Degree of Saturation	0.83	Gs (W / e)
Vw	Volume of Water (L/L soil)	0.33	S x Vv
Va	Volume of Air (L/L soil)	0.07	Vv - Vw
p	Bulk Density (kg/L soil)	1.92	Yd + (Vw x Yw) or Yw[Gs+(S x e)] / 1+e 1.92
A	Air Filled Volume (L air/kg soil)	0.034	Va / p
Kb	**Biodegradation Rate (mg TPH/kg soil/yr)**	**2650**	**(ko x A x Do x C x 8760 hr per yr) / 100**

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BIODEGRADATION RATE CALCULATIONS

Site: South Gas Station
Location: Travis AFB, California
Soil Smpl.Depth: 15.5 ft. bgs
VEW/VMP: VMP-2-14

Measurements and Assumptions			
ko	Oxygen Utilization Rate (%/hr)	2.30	assumed for measured value for VMP-2-6
W	Moisture Content	0.210	laboratory measurement
	Soil Type	CLAY;silty	field observation
Gs	Specific Gravity (grain density)	2.65	estimated based on Gs of quartz
n	Porosity	0.38	estimated from soil type
	TRPH + BTEX Concentration (mg/kg)	93.600	laboratory measurement
Constants			
Yw	Unit Weight of Water (g/cm3)	1.00	known constant
Do	Density of Oxygen (mg/L)	1340	known constant
C	Carbon/Oxygen Ratio	0.29	assumed 1/3.5 mass ratio required for degradation
Calculated Data			
Yd	Dry Unit Weight (g/cm3)	1.64	Yw x Gs (1 - n)
Vv	Volume of Voids (L/L soil)	0.38	n x 1 liter
e	Void Ratio	0.61	n / (1-n)
S	Degree of Saturation	0.91	Gs (W / e)
Vw	Volume of Water (L/L soil)	0.35	S x Vv
Va	Volume of Air (L/L soil)	0.03	Vv - Vw
p	Bulk Density (kg/L soil)	1.99	Yd + (Vw x Yw) or Yw[Gs+(S x e)] / 1+e 1.99
A	Air Filled Volume (L air/kg soil)	0.018	Va / p
Kb	**Biodegradation Rate (mg TPH/kg soil/yr)**	**1357**	**(ko x A x Do x C x 8760 hr per yr) / 100**

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BIODEGRADATION RATE CALCULATIONS

Site: South Gas Station
Location: Travis AFB, California
Soil Smpl.Depth: None
VEW/VMP: VEW-2

Measurements and Assumptions			
ko	Oxygen Utilization Rate (%/hr)	2.90	calculated from field ISR test
W	Moisture Content	0.187	estimated from soil type (= VEW-1)
	Soil Type	SAND;silty;damp loose;well-sort	field observation
Gs	Specific Gravity (grain density)	2.65	estimated based on Gs of quartz
n	Porosity	0.40	estimated from soil type
	TRPH + BTEX Concentration (mg/kg)		
Constants			
Yw	Unit Weight of Water (g/cm3)	1.00	known constant
Do	Density of Oxygen (mg/L)	1340	known constant
C	Carbon/Oxygen Ratio	0.29	assumed 1/3.5 mass ratio required for degradation
Calculated Data			
Yd	Dry Unit Weight (g/cm3)	1.59	Yw x Gs (1 - n)
Vv	Volume of Voids (L/L soil)	0.40	n x 1 liter
e	Void Ratio	0.67	n / (1-n)
S	Degree of Saturation	0.74	Gs (W / e)
Vw	Volume of Water (L/L soil)	0.30	S x Vv
Va	Volume of Air (L/L soil)	0.10	Vv - Vw
p	Bulk Density (kg/L soil)	1.89	Yd + (Vw x Yw) or Yw[Gs+(S x e)] / 1+e 1.89
A	Air Filled Volume (L air/kg soil)	0.054	Va / p
Kb	**Biodegradation Rate (mg TPH/kg soil/yr)**	**5291**	**(ko x A x Do x C x 8760 hr per yr) / 100**

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BIODEGRADATION RATE CALCULATIONS

Site: Fuel Storage Area G (Site 1)
Location: Travis AFB, California
Soil Smpl.Depth: 6.0 ft. bgs
VEW/VMP: VW-1

Measurements and Assumptions			
ko	Oxygen Utilization Rate (%/hr)	2.80	calculated from field ISR test
W	Moisture Content	0.148	laboratory measurement
	Soil Type	SAND;fine/SILT;cly, stiff,plastic,damp	field observation
Gs	Specific Gravity (grain density)	2.65	estimated based on Gs of quartz
n	Porosity	0.35	estimated from soil type
	TRPH + BTEX Concentration (mg/kg)	0.104	laboratory measurement
Constants			
Yw	Unit Weight of Water (g/cm3)	1.00	known constant
Do	Density of Oxygen (mg/L)	1340	known constant
C	Carbon/Oxygen Ratio	0.29	assumed 1/3.5 mass ratio required for degradation
Calculated Data			
Yd	Dry Unit Weight (g/cm3)	1.72	Yw x Gs (1 - n)
Vv	Volume of Voids (L/L soil)	0.35	n x 1 liter
e	Void Ratio	0.54	n / (1-n)
S	Degree of Saturation	0.73	Gs (W / e)
Vw	Volume of Water (L/L soil)	0.25	S x Vv
Va	Volume of Air (L/L soil)	0.10	Vv - Vw
p	Bulk Density (kg/L soil)	1.98	Yd + (Vw x Yw) . or Yw[Gs+(S x e)] / 1+e 1.98
A	Air Filled Volume (L air/kg soil)	0.048	Va / p
Kb	**Biodegradation Rate (mg TPH/kg soil/yr)**	**4515**	**(ko x A x Do x C x 8760 hr per yr) / 100**

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BIODEGRADATION RATE CALCULATIONS

Site: Fuel Storage Area G (Site 1)
Location: Travis AFB, California
Soil Smpl.Depth: None
VEW/VMP: VMP-1-3.5

Measurements and Assumptions			
ko	Oxygen Utilization Rate (%/hr)	3.10	calculated from field ISR test
W	Moisture Content	0.160	estimated from soil type
	Soil Type	SILT; clayey,stiff,dam	field observation
Gs	Specific Gravity (grain density)	2.65	estimated based on Gs of quartz
n	Porosity	0.35	estimated from soil type
	TRPH + BTEX Concentration (mg/kg)		laboratory measurement
Constants			
Yw	Unit Weight of Water (g/cm3)	1.00	known constant
Do	Density of Oxygen (mg/L)	1340	known constant
C	Carbon/Oxygen Ratio	0.29	assumed 1/3.5 mass ratio required for degradation
Calculated Data			
Yd	Dry Unit Weight (g/cm3)	1.72	Yw x Gs (1 - n)
Vv	Volume of Voids (L/L soil)	0.35	n x 1 liter
e	Void Ratio	0.54	n / (1-n)
S	Degree of Saturation	0.79	Gs (W / e)
Vw	Volume of Water (L/L soil)	0.28	S x Vv
Va	Volume of Air (L/L soil)	0.07	Vv - Vw
p	Bulk Density (kg/L soil)	2.00	Yd + (Vw x Yw) or Yw[Gs+(S x e)] / 1+e 2.00
A	Air Filled Volume (L air/kg soil)	0.037	Va / p
Kb	**Biodegradation Rate (mg TPH/kg soil/yr)**	3871	(ko x A x Do x C x 8760 hr per yr) / 100

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BIODEGRADATION RATE CALCULATIONS

Site: Fuel Storage Area G (Site 1)
Location: Travis AFB, California
Soil Smpl.Depth: 6.0 ft. bgs
VEW/VMP: VMP-1-6

Measurements and Assumptions			
ko	Oxygen Utilization Rate (%/hr)	4.30	calculated from field ISR test
W	Moisture Content	0.164	laboratory measurement
	Soil Type	SILT;cly,stiff,damp	field observation
Gs	Specific Gravity (grain density)	2.65	estimated based on Gs of quartz
n	Porosity	0.35	estimated from soil type
	TRPH + BTEX Concentration (mg/kg)	0.108	laboratory measurement
Constants			
Yw	Unit Weight of Water (g/cm3)	1.00	known constant
Do	Density of Oxygen (mg/L)	1340	known constant
C	Carbon/Oxygen Ratio	0.29	assumed 1/3.5 mass ratio required for degradation
Calculated Data			
Yd	Dry Unit Weight (g/cm3)	1.72	Yw x Gs (1 - n)
Vv	Volume of Voids (L/L soil)	0.35	n x 1 liter
e	Void Ratio	0.54	n / (1-n)
S	Degree of Saturation	0.81	Gs (W / e)
Vw	Volume of Water (L/L soil)	0.28	S x Vv
Va	Volume of Air (L/L soil)	0.07	Vv - Vw
p	Bulk Density (kg/L soil)	2.00	Yd + (Vw x Yw) or Yw[Gs+(S x e)] / 1+e 2.00
A	Air Filled Volume (L air/kg soil)	0.034	Va / p
Kb	**Biodegradation Rate (mg TPH/kg soil/yr)**	**4856**	**(ko x A x Do x C x 8760 hr per yr) / 100**

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BIODEGRADATION RATE CALCULATIONS

Site: Fuel Storage Area G (Site 1)
Location: Travis AFB, California
Soil Smpl.Depth: 6.0 ft. bgs
VEW/VMP: VMP-2-5

Measurements and Assumptions			
ko	Oxygen Utilization Rate (%/hr)	4.00	calculated from field ISR test
W	Moisture Content	0.143	laboratory measurement
	Soil Type	SILT;cly,stiff,damp sli plastic	field observation
Gs	Specific Gravity (grain density)	2.65	estimated based on Gs of quartz
n	Porosity	0.35	estimated from soil type
	TRPH + BTEX Concentration (mg/kg)	21.680	laboratory measurement
Constants			
Yw	Unit Weight of Water (g/cm3)	1.00	known constant
Do	Density of Oxygen (mg/L)	1340	known constant
C	Carbon/Oxygen Ratio	0.29	assumed 1/3.5 mass ratio required for degradation
Calculated Data			
Yd	Dry Unit Weight (g/cm3)	1.72	Yw x Gs (1 - n)
Vv	Volume of Voids (L/L soil)	0.35	n x 1 liter
e	Void Ratio	0.54	n / (1-n)
S	Degree of Saturation	0.70	Gs (W / e)
Vw	Volume of Water (L/L soil)	0.25	S x Vv
Va	Volume of Air (L/L soil)	0.10	Vv - Vw
p	Bulk Density (kg/L soil)	1.97	Yd + (Vw x Yw) or Yw[Gs+(S x e)] / 1+e 1.97
A	Air Filled Volume (L air/kg soil)	0.053	Va / p
Kb	**Biodegradation Rate (mg TPH/kg soil/yr)**	**7064**	**(ko x A x Do x C x 8760 hr per yr) / 100**

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BIODEGRADATION RATE CALCULATIONS

Site: Fuel Storage Area G (Site 1)
Location: Travis AFB, California
Soil Smpl.Depth: 9.0 ft. bgs
VEW/VMP: VMP-2-9

Measurements and Assumptions				
ko	Oxygen Utilization Rate (%/hr)	3.80	assumed from average of other VMPs at site	
W	Moisture Content	0.140	estimated from soil type	
	Soil Type	SAND;stiff to loose, damp,sli plastic	field observation	
Gs	Specific Gravity (grain density)	2.65	estimated based on Gs of quartz	
n	Porosity	0.35	estimated from soil type	
	TRPH + BTEX Concentration (mg/kg)	310.000	laboratory measurement	
Constants				
Yw	Unit Weight of Water (g/cm3)	1.00	known constant	
Do	Density of Oxygen (mg/L)	1340	known constant	
C	Carbon/Oxygen Ratio	0.29	assumed 1/3.5 mass ratio required for degradation	
Calculated Data				
Yd	Dry Unit Weight (g/cm3)	1.72	Yw x Gs (1 - n)	
Vv	Volume of Voids (L/L soil)	0.35	n x 1 liter	
e	Void Ratio	0.54	n / (1-n)	
S	Degree of Saturation	0.69	Gs (W / e)	
Vw	Volume of Water (L/L soil)	0.24	S x Vv	
Va	Volume of Air (L/L soil)	0.11	Vv - Vw	
p	Bulk Density (kg/L soil)	1.96	Yd + (Vw x Yw) or Yw[Gs+(S x e)] / 1+e	1.96
A	Air Filled Volume (L air/kg soil)	0.055	Va / p	
Kb	**Biodegradation Rate (mg TPH/kg soil/yr)**	**7064**	**(ko x A x Do x C x 8760 hr per yr) / 100**	

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BIODEGRADATION RATE CALCULATIONS

Site: Fuel Storage Area G (Site 1)
Location: Travis AFB, California
Soil Smpl.Depth: None
VEW/VMP: VMP-3-3.5

Measurements and Assumptions			
ko	Oxygen Utilization Rate (%/hr)	3.80	assumed from average of other VMPs at site
W	Moisture Content	0.170	estimated from soil type
	Soil Type	CLAY;slty/SILT;cly, stiff,plastic,damp	field observation
Gs	Specific Gravity (grain density)	2.65	estimated based on Gs of quartz
n	Porosity	0.35	estimated from soil type
	TRPH + BTEX Concentration (mg/kg)		laboratory measurement
Constants			
Yw	Unit Weight of Water (g/cm3)	1.00	known constant
Do	Density of Oxygen (mg/L)	1340	known constant
C	Carbon/Oxygen Ratio	0.29	assumed 1/3.5 mass ratio required for degradation
Calculated Data			
Yd	Dry Unit Weight (g/cm3)	1.72	Yw x Gs (1 - n)
Vv	Volume of Voids (L/L soil)	0.35	n x 1 liter
e	Void Ratio	0.54	n / (1-n)
S	Degree of Saturation	0.84	Gs (W / e)
Vw	Volume of Water (L/L soil)	0.29	S x Vv
Va	Volume of Air (L/L soil)	0.06	Vv - Vw
p	Bulk Density (kg/L soil)	2.02	Yd + (Vw x Yw) or Yw[Gs+(S x e)] / 1+e 2.02
A	Air Filled Volume (L air/kg soil)	0.028	Va / p
Kb	**Biodegradation Rate (mg TPH/kg soil/yr)**	**3615**	**(ko x A x Do x C x 8760 hr per yr) / 100**

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BIODEGRADATION RATE CALCULATIONS

Site: Fuel Storage Area G (Site 1)
Location: Travis AFB, California
Soil Smpl.Depth: None
VEW/VMP: VMP-3-6.5

Measurements and Assumptions			
ko	Oxygen Utilization Rate (%/hr)	3.90	calculated from field ISR test
W	Moisture Content	0.170	estimated from soil type
	Soil Type	CLAY;slty/SILT;cly, stiff,plastic,damp	field observation
Gs	Specific Gravity (grain density)	2.65	estimated based on Gs of quartz
n	Porosity	0.35	estimated from soil type
	TRPH + BTEX Concentration (mg/kg)		laboratory measurement
Constants			
Yw	Unit Weight of Water (g/cm3)	1.00	known constant
Do	Density of Oxygen (mg/L)	1340	known constant
C	Carbon/Oxygen Ratio	0.29	assumed 1/3.5 mass ratio required for degradation
Calculated Data			
Yd	Dry Unit Weight (g/cm3)	1.72	Yw x Gs (1 - n)
Vv	Volume of Voids (L/L soil)	0.35	n x 1 liter
e	Void Ratio	0.54	n / (1-n)
S	Degree of Saturation	0.84	Gs (W / e)
Vw	Volume of Water (L/L soil)	0.29	S x Vv
Va	Volume of Air (L/L soil)	0.06	Vv - Vw
p	Bulk Density (kg/L soil)	2.02	Yd + (Vw x Yw) or Yw[Gs+(S x e)] / 1+e 2.02
A	Air Filled Volume (L air/kg soil)	0.028	Va / p
Kb	**Biodegradation Rate (mg TPH/kg soil/yr)**	3711	(ko x A x Do x C x 8760 hr per yr) / 100

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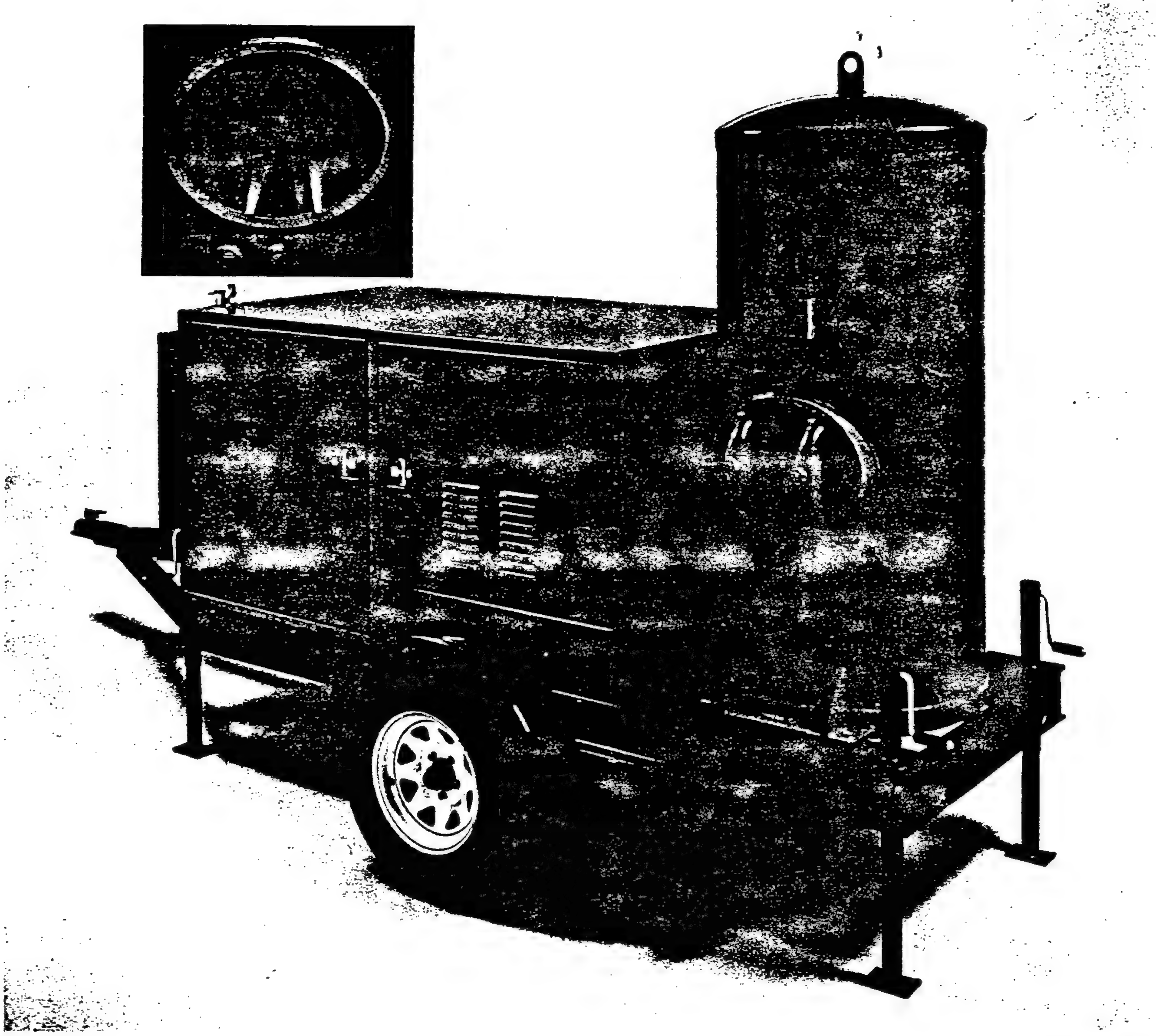
APPENDIX E

DETAILS ON S.A.V.E.™ SYSTEM

The S.A.V.E.™ System

Combined Treatment for Contaminated Soil, Groundwater and Free Floating Product



U.S. Patent No. 4,979,886

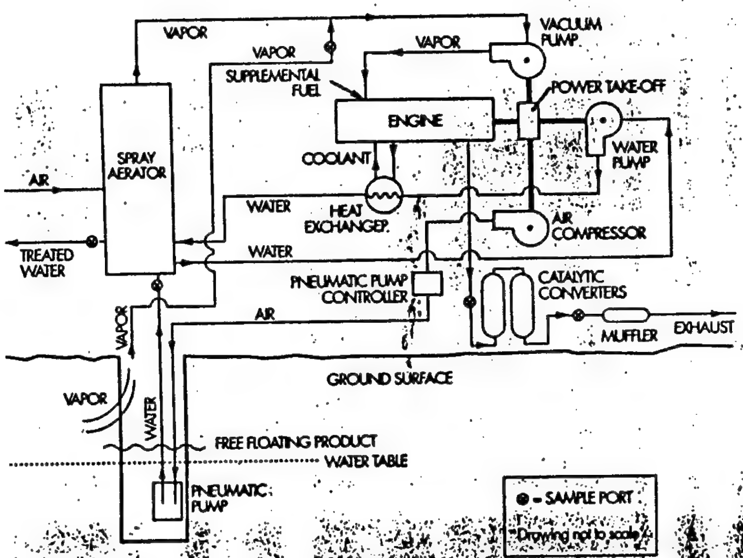
AN ADVANCED SOLUTION

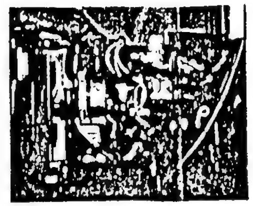
The RSI S.A.V.E. System combines air stripping, vacuum extraction and combustion technologies to provide a complete remediation package. Capable of treating contaminated soil, groundwater and free floating product, the S.A.V.E. System offers significant advantages over conventional remediation methods. Our process has been sited by the California Regional Water Quality Control Board as the best available technology economically achievable for the treatment of gasoline contaminated groundwater.

RSI®

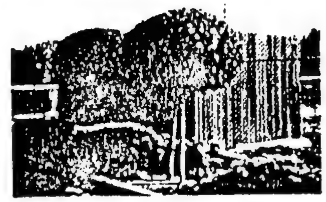
Remediation Service, Int'l.

Spray Aeration Vacuum Extraction, The S.A.V.E. System.



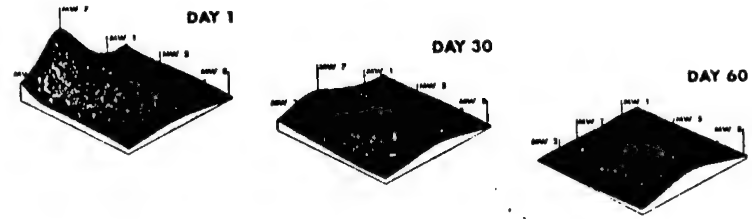


The engine is accessible from both sides of the housing for easy maintenance.



The compact S.A.V.E. System can be easily installed in an aesthetically designed enclosure.

Actual site data showing change in free product thickness over time.



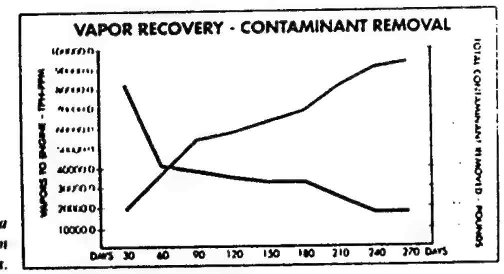
"The cost of environmental compliance is of major concern to all independent oil marketers. RSI has provided a solution to the high cost of remediation. Their S.A.V.E. technology has proven to be a cost effective way to remediate our facility. We are able to perform the routine maintenance ourselves, saving thousands of dollars over the duration of the cleanup. We are pleased to recommend RSI and it's S.A.V.E. remediation equipment."

-Mark McCarthy, Operations Manager
Giant Truck Stops

"After careful review of available treatment systems and technologies, On-Site Technologies, Inc. recommended and installed the RSI S.A.V.E. System for one of our clients. The S.A.V.E. technology was selected in part because of its ability to simultaneously remediate contaminates from the soil and groundwater as well as floating product effectively and efficiently. Since start-up, the S.A.V.E. equipment has performed to our expectations and standards."

-Chris L. Lindskog, Vice President
On-Site Technologies, Inc.

Graphs of actual site data display S.A.V.E. System recovery & removal results.



GROUNDWATER REMEDIATION

The RSI S.A.V.E. System remediates water contamination using spray aeration. Unlike air strippers which move air quickly over the surface of hydrocarbon laden water, spray aeration accomplishes volatilization by spraying water droplets containing hydrocarbons into the air. Combining vacuum and heat with spray aeration enhances the separation of hydrocarbons in two ways. First, with reduced pressure the temperature at which hydrocarbons vaporize drops. Second, an increase in temperature from the addition of heat generated by the engine increases the potential for hydrocarbon vaporization further. By spraying heated water into a vacuum, the S.A.V.E. System takes advantage of both these principles. This combination of technology makes the S.A.V.E. System significantly more effective at hydrocarbon separation than conventional air stripper systems.

The S.A.V.E. System is more cost effective too. With no costly packing material to foul or replace, the major maintenance expense of an air stripper is completely eliminated.

SOIL VENTING/ COMBUSTION CONTROL

The soil vacuum extraction system consists of a vacuum pump driven by an internal combustion engine. The vacuum on the extraction well causes hydrocarbons to volatilize and flow up to the vacuum pump. Vapors drawn by the vacuum are then combined with hydrocarbon vapors stripped from the groundwater and directed to the engine intake where they are burned as part of the normal combustion process.

Emissions from the engine are passed through a small catalytic converter to insure maximum destruction of removed hydrocarbons. The engine's fuel to air ratio is adjusted to maintain efficient combustion.

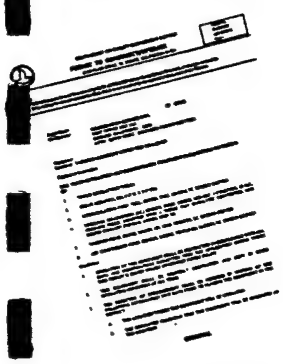
Because the engine is the power source for all equipment, all systems stop when the engine stops. This eliminates any uncontrolled release of hydrocarbons into the atmosphere. And since the system is held entirely under vacuum, any leaks in the seals or connections are into the system. The engine also features shut off devices triggered by loss of vacuum, low oil pressure or engine overheating.

FREE PRODUCT REMOVAL

S.A.V.E. System vacuum extraction is proven effective for removing free phase liquid volatile hydrocarbons floating on the water table. Our technology is more efficient than traditional skimming for three reasons. First, as free product thickness decreases, recovery rates from free product pumping also decrease. This is because most of the product is contained in the capillary fringe and is under the force of a capillary vacuum. The S.A.V.E. System overcomes this barrier because the induction of air flow over the product and subsequent in-site volatilization are not affected by capillary forces. Second, the S.A.V.E. System creates a vacuum in the recovery well which counteracts capillary forces and draws liquid hydrocarbons into the well more quickly. Finally, since the recovered free product is completely destroyed as fuel in the engine, there is no need for costly storage or disposal of liquid hydrocarbons.

REGULATORY ACCEPTANCE

The S.A.V.E. System is permitted for use throughout California, and is gaining widespread approvals in many other states as well. The system meets or exceeds air quality standards in all California air quality districts including the South Coast Air Quality Management District and the Bay Area Air Pollution Control District. RSI maintains groundwater discharge permits from the National Pollutant Discharge Elimination System (NPDES) and numerous local sanitary districts. The California Regional Water Quality Control Board has termed S.A.V.E. technology as the best economically achievable method available for the treatment of gasoline contaminated groundwater.



DISTRIBUTION AND SERVICE

RSI maintains a network of authorized service contractors and distributors throughout the nation. Please contact RSI for the contractor or distributor in your area.

SPECIFICATIONS

ELECTRICAL REQUIREMENTS
None

ENGINE
RPM 1,500 - 2,300 site specific (Specifications based on 2,000 RPM)

FUEL SOURCE
Well Flow/Contamination, Natural Gas, Propane or Combination of Well Flow and Alternate Fuel

FUEL CONSUMPTION
Propane
1.5 gallons /hour maximum
1.1 gallons /hour typical
Natural Gas
135 cfh maximum
100 cfh typical (.94 therm/hour)
Well Flow
site specific
btu's
126,500 btu's/hour maximum
93,600 btu's/hour typical

TOTAL FRESH AIR/FUEL FLOW
80 cfm maximum, 40-80 cfm typical

WELL FLOW
0-80 cfm, site specific

FRESH AIR FLOW
0-80 cfm, site specific

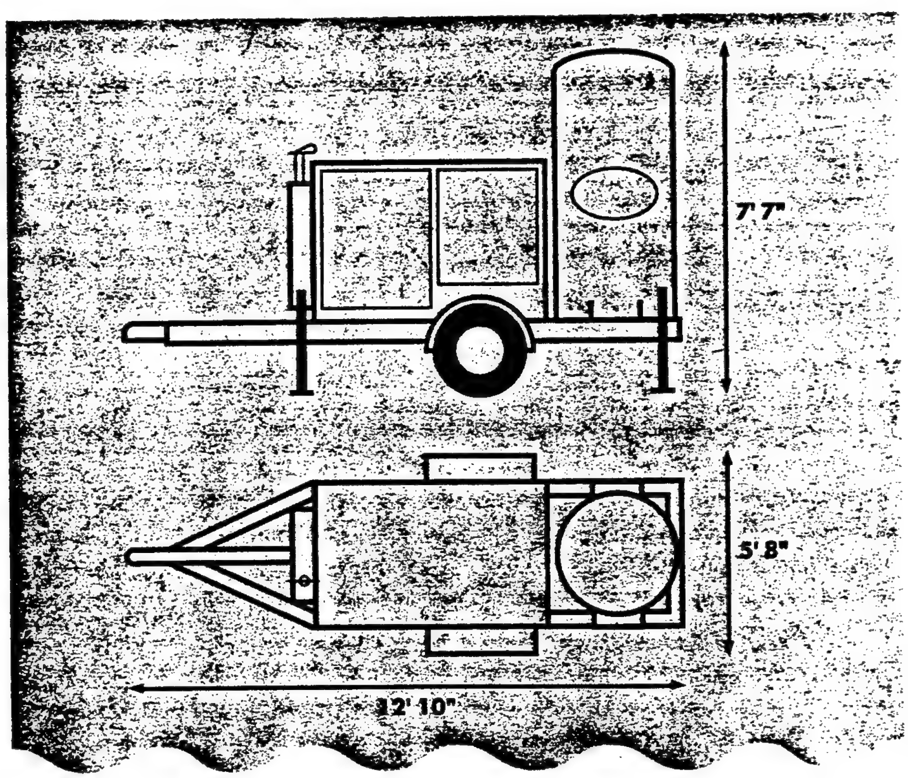
COMBUSTION EFFICIENCY WITH CATALYTIC CONVERTER
99.9 % with proper service and maintenance

VACUUM /WELL MANIFOLD
0" to 15" Hg, site specific

WATER TREATMENT EFFICIENCY
0-10 gpm up to 99.9%
above 10 gpm site specific

NOISE LEVEL
Less than 70 db at 20 feet

SHIPPING WEIGHT
≈2,850 lbs.



For additional information, please contact:

Remediation Service, Int'l.
P.O. Box 1601 Oxnard, CA 93032
Telephone (805) 644-5892
FAX (805) 654-0720

REMEDIATION SERVICE, INT'L.

OVERVIEW OF RSI'S VAPOR EXTRACTION TESTING SERVICES

Remediation Service, Int'l (RSI) conducts soil vapor extraction tests using RSI's patented Spray Aeration Vacuum Extraction (S.A.V.E.) System. The vacuum extraction portion of the S.A.V.E. System consists of a vacuum pump driven by an internal combustion engine. The vacuum pump is connected to an extraction well and the vacuum created on the extraction well causes hydrocarbons in the soil to volatilize and flow through the vacuum pump to the internal combustion engine where they are burned as part of the normal combustion process. Propane or natural gas is used as an auxiliary fuel to assist combustion, when necessary.

Emissions from the engine are passed through a small catalytic converter to insure maximum destruction of removed hydrocarbon vapors. The engine's fuel to air ratio can be adjusted to maintain efficient combustion. The engine is the power source for all equipment and automatically stops when vacuum loss, low oil pressure or overheating occurs. This eliminates any uncontrolled release of hydrocarbons. And since the system is held entirely under vacuum, any leaks in the seals or connections are into the system.

System parameters are monitored using Magnahelic vacuum gauges, a Horiba exhaust analyzer, an Enerac exhaust analyzer and the flow controls on the S.A.V.E. System. Induced vacuum pressures are monitored at surrounding monitoring wells or probes using Magnahelic vacuum gauges.

For the basic vapor extraction test, RSI provides a S.A.V.E. unit, monitoring and sampling equipment, and a qualified technician to operate the S.A.V.E. and collect samples. The technician operates at the direction of the client and technician will deliver any samples to the laboratory. When analytical results are received by RSI the results are forwarded to the client along with all collected data in table form. On client directed tests, RSI is not responsible for test methodology or data interpretation. Rates for the basic client directed test are based on the use of the equipment and operator for one day, collection of three vapor samples and analysis of the three vapor samples by a state certified laboratory for total petroleum hydrocarbons (TPH) plus benzene, toluene, ethylbenzene and total xylenes (BTEX).

RSI also offers professional services to design and conduct site specific tests and interpretation. Vapor extraction tests are designed based upon client provided data. RSI engineered vapor extraction tests are available.

REMEDIATION SERVICE, INT'L.

RSI'S ENGINEERED VAPOR EXTRACTION TESTS

RSI offers professional services to design and conduct site specific vapor extraction tests and the interpretation of test results. Vapor extraction tests are designed to provide maximum data in an economic manner based on client provided data concerning the site. Specific tests include:

1. Radius of Influence Tests
2. Variable Rate Flow Tests
3. Contaminant Removal Rates and Destruction Efficiency

The radius of influence defines the region within which the vapor in the vadose zone flows to the extraction well under the influence of a vacuum. The radius of influence depends on soil properties of the vented zone, properties of surrounding soil layers, the depth at which the well is screened, and the presence of any impermeable boundaries such as the water table, clay layers, surface seal, building basements, etc. An estimate of the radius of influence can be obtained by plotting radial pressure distribution equations. Radial pressure distribution data is collected by placing a vacuum on an extraction well and measuring the induced vacuum over time at various monitoring points surrounding the extraction well. Radius of influence data can be used to estimate the number and spacing of extraction wells necessary for efficient remediation by soil vapor extraction.

The purpose of a variable rate flow is to define the pressure/flow characteristics of the subsurface soils around an extraction well. Pressure/flow characteristics are determined by extracting vapors from a well at various flow rates and recording the corresponding vacuum pressure. A plot of this data can be used to estimate potential conditions for an operational soil venting system.

Initial contaminant removal rates can be estimated from measured flow rates and the result of laboratory analytical data from samples collected during the vapor extraction test. Destruction rates can be determined by comparing the analytical results of inlet and exhaust vapor samples collected simultaneously during the test. Vapor samples are generally analyzed for TPH and BTEX but additional analyses can be performed based on the types of contaminants thought to be present at the site.

RCI REMEDIATION SERVICE, INT'L.
P.O. BOX 1601, OXNARD, CALIFORNIA 93032
(805) 644-5892 • FAX (805) 654-0720

The following is a partial list of agency permits for the S.A.V.E. System. For ease of reference, they are grouped by jurisdiction. Client names are not included for confidentiality reasons.

Air Pollution Control District's Permits (partial list):

County/Agency	City	Permit/Application No.
Bay Area AQMD	Burlingame	4540
	Castro Valley	3848
	Oakland	4543
	Oakland	4572
	San Carlos	6254
	San Jose	4709
	San Jose	6291
	San Jose	7152
	San Jose	2487
	San Jose	3057
	San Francisco	1702
	San Francisco	1703
	San Francisco	8401
	Santa Clara	1993
	Saratoga	4811
Fresno APCD	Fresno	exempt
Imperial County APCD	Calexico	exempt
Kings County APCD	Hanford	exempt
Lassen County APCD	various	exempt
Modoc County APCD	Alturas	exempt
North Cost Unified AQMD	Eureka	exempt
Placer County APCD	Auburn	exempt
Santa Barbara APCD	Santa Barbara	7122
South Coast AQMD	Anaheim	189055
	Artesia	172049
	Brea	172052
	South El Monte	176917
	Fountain Valley	175869
	Garden Grove	175868
	Irvine	226872
	Laguna Beach	190876

Air Pollution Control District's Permits (partial list) - cont'd:

County/Agency	City	Permit/Application No.
	Long Beach	172050
	Long Beach	230769
	North Long Beach	164842
	Paramount	161796
	Pedley	177621
	Rosemead	167513
San Diego APCD	Chula Vista	870996
	Chula Vista	870994
	Imperial Beach	870995
	San Diego	870648
	San Diego	880479
San Luis Obispo APCD	Pismo Beach	1145
Tuolumne County APCD	various	exempt
Ventura County APCD	Oxnard	exempt
	Santa Paula	exempt
	Thousand Oaks	exempt
	Ventura	exempt

S.A.V.E. Water Discharge Permits (partial list):

To Sewer	City	Permit/Application No.
Goleta Sanitary District	Goleta	IV-412
Ventura Regional Sanitation District	Santa Paula	SP0010
East Bay Municipal Utilities District	Oakland	001-00011
Santa Barbara Public Works Department	Santa Barbara	90-018GW

To Storm Drain	City	Permit/Application No.
California Regional Water Quality Control Board (San Francisco Bay Region)	San Jose	493
California Regional Water Quality Control Board Santa Ana Region	Fountain Valley	89-105
California Regional Water Quality Control Board Santa Ana Region	Anaheim	89-145

Reinjection	City	Permit/Application No.
California Regional Water Quality Control Board Santa Ana Region	Irvine	90-159
California Regional Water Quality Control Board Los Angeles Region	Thousand Oaks	89-041

REMEDIATION SERVICE, INT'L.

(S)PRAY (A)ERATION (V)ACUUM (E)XTRACTION EQUIPMENT SPECIFICATIONS

Engine - Power Source/Thermal Oxidizer

Make: Ford
Model: LSG-423P

140 cubic inch displacement (2.3 l), 63 HP, 4 cylinders, propane or natural gas co-fired

Vacuum Pump

Make: Dresser-Roots
Model: 33 RAI Universal
Engine driven, maximum flow 155 scfm
Actual operating flow rates 0-60 scfm

Catalytic Converters

Make: Car Sound Exhaust Systems
Model: ICEN 703

100 cubic feet/minute, temperature 600-1500 degree F
Anticipated life 4,000 hours; performance examination recommended every 500 hours; two in series

Spray Aerator

RSI designed and constructed

Flow rate: 80 scfm vapor/10 gpm water
Actual operating flow rates: 0-60 scfm vapor (site specific)
0-10 gpm water (site specific)
Recirculation: 130 gpm

8 spray nozzles capable of 15 gpm each, which includes 6 re-circulating and 2 primary nozzles
Float activated discharge

Recirculating Pump

Make: Teel
Model: 2P015

130 gpm, 30 psi (70′ head)
Engine driven

Air Compressor

Make: I.M.T.
Model: HD300

12.4 scfm delivered air @ 90 psi

Heat Exchanger

RSI designed and constructed

Thermal finned tube coil

System Dimensions

8.0′ length, 3.5′ width, 6.5′ height
Tank size: 3′ diameter, 6.5′ height
Weight 2,200 lbs.
On trailer, 12′7" l X 4′9" w X 8′ h; 3,000 lbs.

Stack

Height: 10′-14′ (please specify)
Temperature: 600-800 degrees F
Exhaust Pipe: 1 1/2"

Optional Equipment Available
Through R.S.I.

General:

Propane or natural gas supply
Security fencing
Equipment pad
Well installations
DC converter

Soil:

Moisture knockout (see drawing)
Air particle filter (see drawing)
Piping and well head connectors (see drawing)
Test ports (see drawing)

Water:

Oil/water separator
Influent preheater
pH control for total dissolved solids
(2) carbon canisters 200 lbs. each 25 psi
(polishing effluent if necessary for discharge, see drawing)
Air receiver tank (see drawing)
Air filter/air dryer for air compressor
Downwell pneumatic pumps (may require controller system)
Solenoid valve for control of air to pneumatic pumps for emergency shut down
Particle filters for suspended solids
Flow meter for discharge of effluent
Test ports (see drawing)

Technical Support/Maintenance:

Horiba engine analyzer
Enerac 2000 analyzer

* Some optional equipment may be necessary for successful installation of the RSI S.A.V.E. system. Optional equipment varies per site and prices can be quoted upon request. Please contact RSI for further information.